

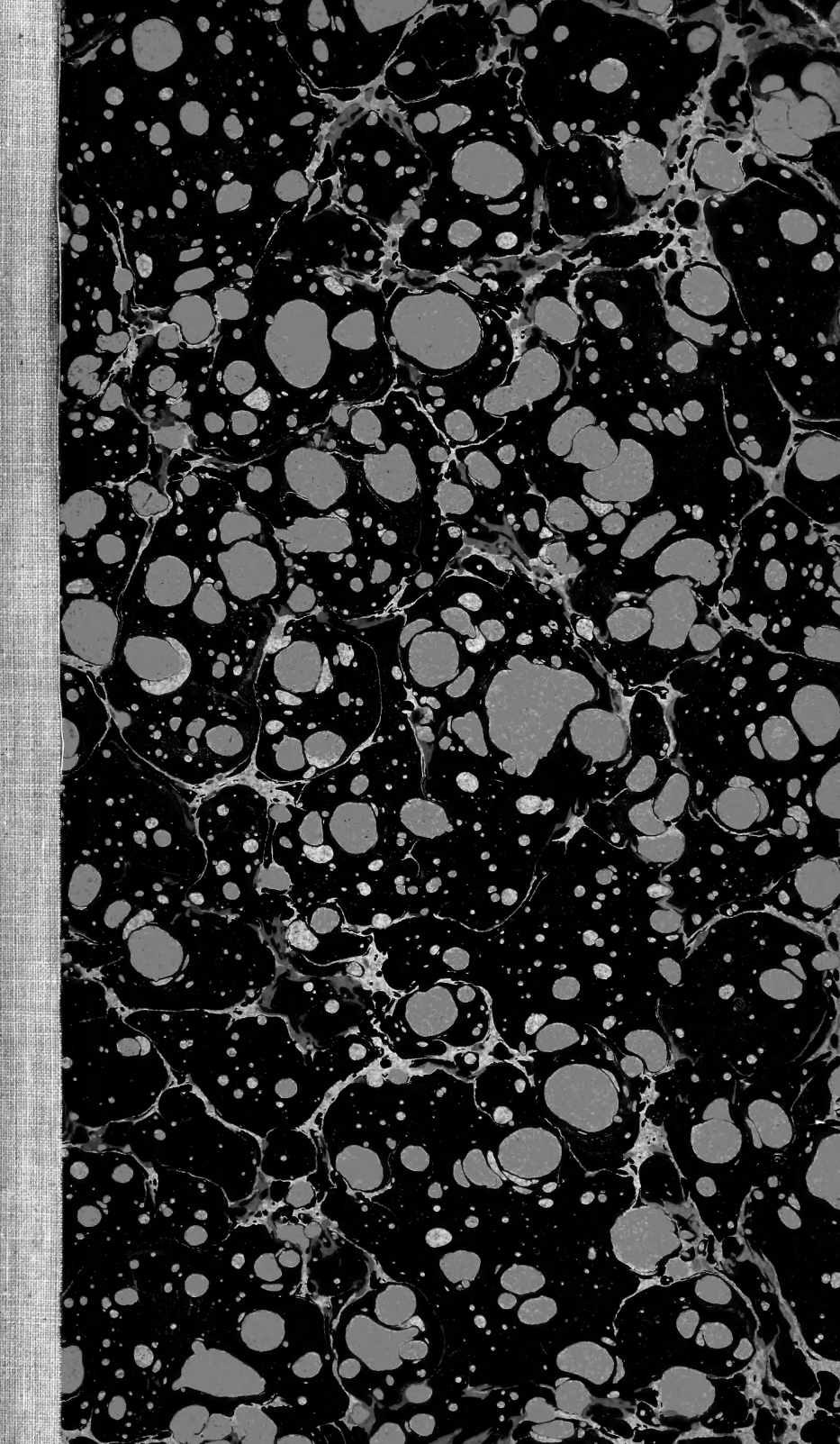


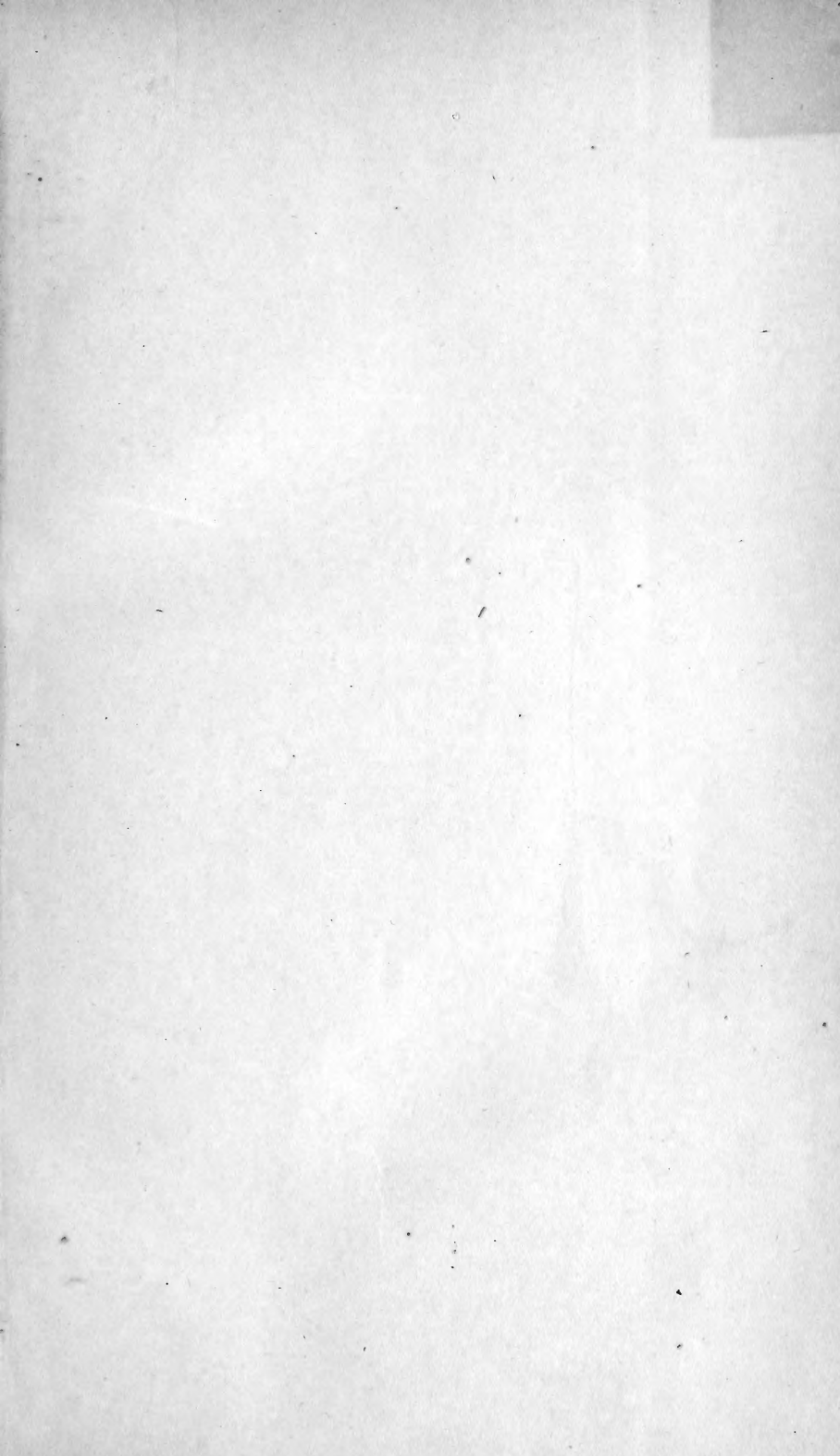
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THE

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

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ERRATA ET CORRIGENDA.

Proc. p. 80, *note*, line 8 from bottom, for "M ca" read "Mica."

Proc. p. 87, last line, for "ndubitably" read "indubitably."

Proc. p. 90, *note*, line 3, for "is" read "in."

Page 35, line 5 from foot, for "180" read "280."

Page 47, line 15, for "third" read "half."

Page 47, line 16, for "2640" read "1760," and for "double" read "treble."

Page 65, line 12, *dele* "out."

Page 69, line 7, for "orphitic" read "ophitic."

Page 79, line 17 from foot, for "slower" read "more rapid."

Page 421, in legend of section, for "rhyolite" read "dacite."

THE
QUARTERLY JOURNAL

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THE GEOLOGICAL SOCIETY OF LONDON.

VOL. XLII.

1. *On the* PREMAYLLARIES *and* SCALPRIFORM TEETH *of a large extinct* WOMBAT (*PHASCOLOMYS CURVIROSTRIS*, OW.). By Sir RICHARD OWEN, K.C.B., F.R.S., F.G.S., &c. (Read November 4, 1885.)

[PLATE I.]

OF the fossils discovered in the late exploration of the Wellington bone-caves, casts of a selection have been transmitted to me for determination by the authorities of the Australian Museum, Sydney, New South Wales.

I submit a description, with figures, of a specimen showing so much of the premaxillary bones (Pl. I. figs. 1-3) as includes the pair of scalpriform incisors (*i, i'*). The length of the tooth, following the outer curve, is 160 millim. ($6\frac{1}{2}$ inches); the transverse breadth is 12 millim.; the antero-posterior diameter is 10 millim.; the length of the worn or working surface is 26 millim. The major part, if not the whole, of the pulp-cavity, exposed at the back part of the fossil (fig. 3), shows the sharp border of the pulp-cavity, *i'*, and the chamber which lodged the persistent organ of growth.

The fore part of the tooth is convex across, the back part feebly so. The implanted portions of the incisors incline towards each other as they approach the hinder open end; the breadth of the pair, there, is 26 millim.

The prominence of the outer walls of the socket gradually increases as it approaches the tooth's base, dividing the premaxillary surface into an upper and lower subvertical tract (fig. 1). The under part of the alveolar wall (fig. 2, 22) loses breadth as it recedes from its

fellow, gradually narrowing as it leaves the tooth's socket, to form a ridge, *r, r*, which expands abruptly at the beginning of the alveolar tract (*m*) for the molar teeth, which tract is broken away with the missing part of the skull. The intervening edentulous tract bounds, with its fellow, a deep subangular anterior palatine depression (fig. 2, *d, d*). The breadth of the unworn incisor equals that of the socket of the same tooth in the extinct *Phascolomys medius**. The contour of the premaxillary palatal ridge extending to the molar tract is deeply arched, viewed sideways (fig. 1 *r*), and is not continued there in an almost straight line, as in *Phascolomys medius*†: the depression at the hinder half of the diastema is also much deeper in the present fossil; the least breadth of this part of the palate is 1 inch.

The premaxillaries rise at their mid upper suture to about an inch from the prominent alveolar tracts of those bones, and unite to form a ridge, augmenting in height as it extends back; the fractured border probably united with the nasal bones, which are wanting in the fossil.

The accompanying figures, of the natural size, of this portion of the skull may enable us to dispense with further description.

Of the animals characterized by the pair of scalpriform incisors the grounds for referring the present large extinct kind to the Marsupial rather than the Rodent order have weighed with me; and until further evidence, especially that supplied by a molar tooth, or teeth, negating the present conclusion, be received, I place it in the Wombat family.

The specimen indicates, therein, a somewhat larger animal than the *Phascolomys medius*, Ow., but one less than the type of the subgenus *Phascolonus*‡. The chief difference from phascolomyidian species, both recent and extinct, of less magnitude, has suggested the *nomen specificum*.

EXPLANATION OF PLATE I.

Portions of the premaxillary bones, including the incisors: nat. size.

Fig. 1. Left side view.

2. Under or palatal surface.

3. Back view, showing pulp-cavities, *i'*, of incisors.

DISCUSSION.

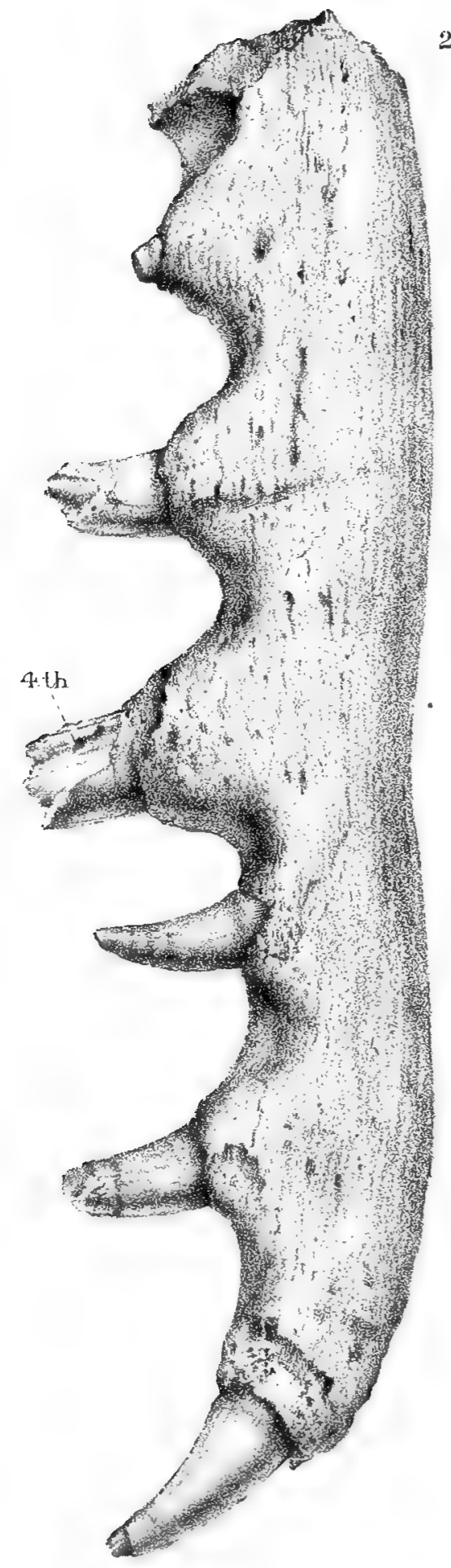
Dr. H. WOODWARD regretted that he had been unable to bring the cast, but would produce it at the next Meeting. The original specimen is in the Sydney Museum. Without molar teeth it is difficult to compare the specimen with other species. There was some resemblance to *Diprotodon*, but it was difficult to go into this in the absence of the cast.

* Fossil Mammals of Australia, 4to, pl. 1. fig. 6.

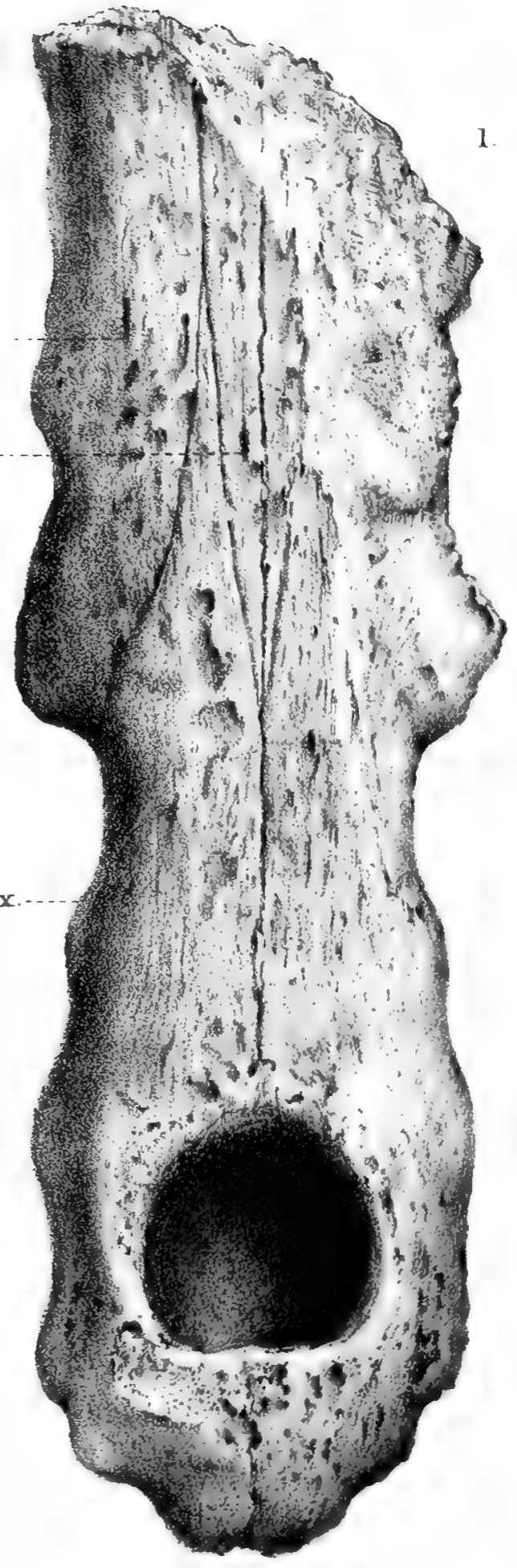
† *Op. cit.* pls. lvii., lviii. fig. 3.

‡ *Op. cit.* vol. i. p. 339, pls. lvii.-lix.





2



1.

2. *Results of recent RESEARCHES in some BONE-CAVES in NORTH WALES (FFYNNON BEUNO and CAE GWYN).* By HENRY HICKS, M.D., F.R.S., F.G.S.; with a NOTE on the ANIMAL REMAINS, by W. DAVIES, Esq., F.G.S. (Read November 18, 1885.)

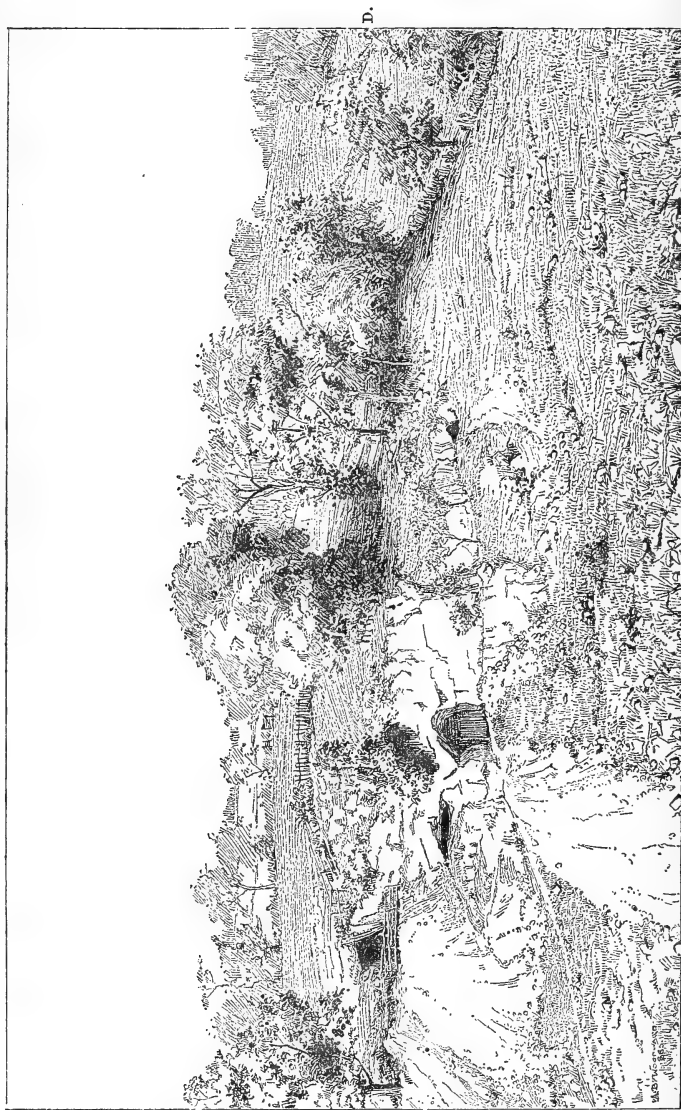
INTRODUCTION.

A SHORT account of these caverns and of some trial examinations made in them by Mr. E. Bouverie Luxmoore, of St. Asaph, and myself, was given by me in a paper read before the Geologists' Association on November 7th, 1884*. No attempt at a systematic exploration, however, was made until the early part of the past summer, when a staff of workmen was employed under the personal supervision of Mr. Luxmoore and myself to excavate the two caverns simultaneously, the funds for the purpose being placed at our disposal by the Royal Society on the recommendation of the Government Grant Committee. The owners of the land, P. P. Pennant, Esq., and Edwin Morgan, Esq., readily gave us permission to carry on the explorations, and frequently during the prosecution of the work we were indebted to them also for many courteous acts and for very valuable assistance.

The caverns are situated in a Carboniferous Limestone escarpment forming the north side of a ravine near Tremeirchion, on the east side of the Vale of Clwyd (fig. 1). The heights of the caverns above sea-level are about 380 and 400 feet, and they are about 42 and 62 feet above the stream in the ravine. Both have their entrances looking towards the south. A reddish Boulder-clay covers the bottom of the ravine and also the slope on the opposite side to a considerable height, and another escarpment of Carboniferous rocks becomes exposed at the higher levels on that side. The stream is gradually deepening its course by cutting through the Boulder-clay, but it has not as yet reached the original floor of the valley. At different points along the valley the Boulder-clay with its associated sands and gravels is left in miniature terraces at various heights, some being above the horizon of the caverns. An important section showing bands of sand and gravel with scratched boulders is to be seen about four hundred feet east of the caverns on the same side of the valley, at the point indicated in the sketch (fig. 1, D). This gravel-pit is slightly above the level of Cae Gwyn Cave. Fragments of shells were found in the sands and gravels here, but they were too imperfect for determination. The boulders and rolled pebbles in this pit are fragments of various rocks, the majority perhaps being of local origin; but there are many among them which must have been derived from very distant sources. The rocks of the hills above, Denbighshire flags and grits, have supplied a large proportion, as also the

* "On some recent Researches in Bone-caves in Wales," Proc. Geologists' Association, vol. ix. No. 1.

Fig. 1 — View showing Position of Ffynnon Beuno and Cae Gwynn Caves, and of the Gravel in the Valley.



A. Entrance of Cae Gwynn Cave.

B. Entrance of Ffynnon Beuno Cave.

C. West Tunnel of Ffynnon Beuno Cave.

D. Sands and gravels, with ice-scratched boulders and shells.

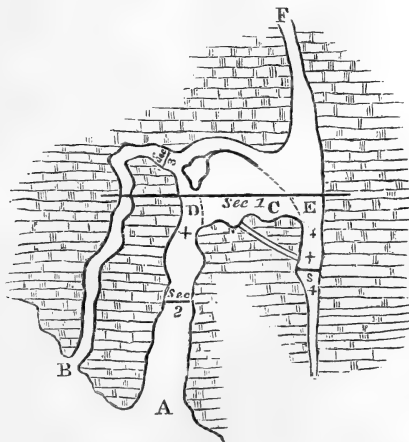
immediately surrounding limestone rocks; but there are also felstones and other igneous rocks from other Welsh areas, and granitic and gneissic rocks from northern sources. Whether the deposits in this exposure belong to the so-called Middle Glacial sands and gravels, or whether they are of the age of the intercalations frequently found in the Upper Boulder-clay of the district, I am not prepared to say. Sands and gravels occur in this area, as is well known from the researches of Mr. D. Mackintosh and others, at much greater elevations. I noticed a considerable deposit in the gorge east of the Oratory in the grounds of St. Beuno's College, at a height of over 500 feet; and Mr. Mackintosh has described such deposits at heights of over 1200 feet on the mountains to the south-east*.

The ravine in which the caverns are situated was doubtless excavated either before or during glacial times, and was filled up with glacial deposits which have since been gradually removed by sub-aerial denudation. Evidence of this fact is furnished by the portions still remaining at various horizons in cliff hollows and at other points, and the sediments in the caverns tend also, in my opinion, to point to the same conclusion.

FFYNNON BEUNO CAVERN.

This cavern (fig. 2) is so named from its proximity to the well-known St. Beuno's Well, which is situated in the ravine. A trial examination was made just within the entrance by Mr. Luxmoore and

Fig. 2.—Ground-plan of *Ffynnon Beuno Cave*.
(Scale, 35 feet to 1 inch.)

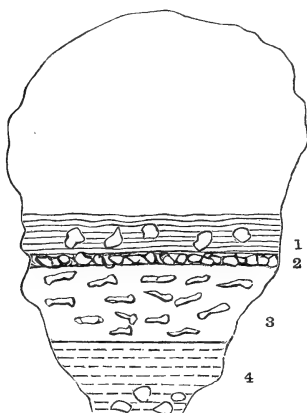


- A. Entrance. B. Opening into west tunnel.
C. Chamber extending from main tunnel, D, to fissure cavern, E.
F. A rapidly descending mining-shaft.
+. Points where flint implements were found in undisturbed earth.

* Quart. Journ. Geol. Soc. vol. xxxvii. p. 360.

myself in the summer of 1883, when a few fragments of bones belonging to the Mammoth and Rhinoceros were found in some cave-earth underlying a stalagmitic breccia. Before this no attempt at exploring the cavern had been made. Much material, however, had probably at different times been removed from the outer portions of this cavern during some mining-operations, and also in order to make it suitable as a sheltering-place for cattle. A considerable heap of rubbish, thrown out at these times on the hill side, still remains, but as yet has not been examined. In our explorations this year we worked inwards from the entrance, removing first the surface soil and afterwards the rather loose stalagmitic breccia and the bone-earth. The underlying material, which will be again referred to, was left in the cavern after testing it at different parts. The section (fig. 3)

Fig. 3.—Section 2 in Ffynnon Beuno Cave.
(Scale, 5 feet to 1 inch.)

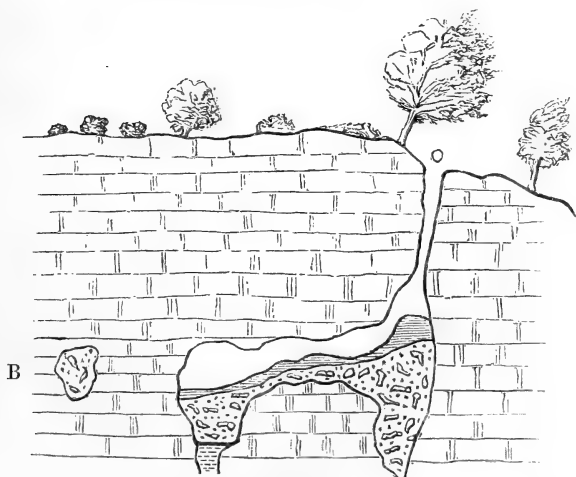


	ft.	in.
1. Surface-soil, &c.	1	0
2. Stalagmitic breccia, with charcoal, &c.	0	6
3. Reddish cave-earth, with bones (<i>Pleistocene</i>) and flint implements, not disturbed	2	0
4. Gravel, consisting mainly of local materials, with angular blocks of limestone below	2	0

represents the conditions found at a distance of about 20 feet from the entrance, and fairly explains the order and thickness of the materials between this and the entrance. There was an open space averaging from 5 to 7 feet up to this point. The surface loam (1), about one foot in thickness, contained a few bones of sheep, the domestic fowl, &c., but no implements or other evidences of early human occupation. The whole was probably accumulated in very recent times. Immediately under this, we found on the west side of the cavern at distances of from 20 to 24 feet from the entrance, a considerable amount of charcoal, but no implements or other evidences with it to give an idea of its age. It may be Neo-

lithic, but as this portion has been open during modern times, it may even possibly be of much later date. 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 in an apparently undisturbed condition. It had an average depth here of about 2 feet. Bones occurred in it in considerable abundance, chiefly lying horizontally or but slightly inclined. 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. In the lower part of this deposit some large angular fragments of limestone occurred, and these also seemed to fill up a narrow fissure-like space below the deposit. Between this point and the chamber C (fig. 2) there was a greater accumulation of surface-soil, but the other deposits occurred much as in fig. 3 (sect. 2). Near D a flint implement was discovered under the stalagmitic breccia, in close proximity to a large portion of the jaw with teeth of a Rhinoceros, which unfortunately fell to pieces in being removed. Some large fragments of limb-bones of Mammoth were also found at this point, but they were so friable that they could not be removed entire. The chamber which forms a communication between the tunnel-cavern D, and the fissure-cavern E (see figs. 2 and 4), seems as

Fig. 4.—*Vertical Section (Sect. 1) across chamber, &c., Ffynnon Beuno Cave.* (Scale, 20 feet to 1 inch.)



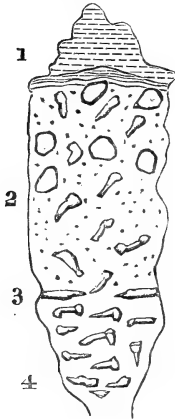
o. Opening in roof above fissure-cavern.

B. West tunnel.

if it had been, in parts, artificially made during mining-operations in order to reach the shaft F. Its floor also is at a much higher level than are the floors in other parts of the caverns. All the materials

found in this chamber appear to have been disturbed and as if they had been thrown into it from some other part of the cavern. On removing the surface-soil which had fallen in through the opening O (fig. 4) and some large masses of limestone, many bones were found in the underlying disturbed material, and also a few broken flint implements. In the line of the fissure there was a thickness, in some places of over 6 feet, of this disturbed earth containing bones lying

Fig. 5.—Section 4 in *Ffynnon Beuno Cave*.



- 1. Surface-soil, &c.
- 2. Sandy loam, with blocks of limestone, &c. containing bones. Disturbed by man
- 3. Stalagmite.
- 4. Cave-earth, with bones and flint implements, not disturbed

ft. in.

6 0

3 0

above the undisturbed portion, the division between the disturbed and the undisturbed earth in one place being still indicated by a portion of an unbroken stalagmite floor. Under this floor (see fig. 5, sect. 4) the bones occurred in a cave-earth like that in chamber D, and here, in close proximity to a Mammoth tooth, a well-worked nearly perfect flint implement was discovered (fig. 6). A communicating tunnel was found to connect this part of the fissure cavern with the main cavern; its direction is indicated by the dotted line in fig. 2. The roof of this tunnel had for a considerable distance been broken through, but the contents seemed to have been left undisturbed by man. The materials here were not exactly in the condition of the deposits shown in fig. 3, and they must have in parts been reassorted by water-action, as a considerable amount of a sandy material and some clay with boulders occurred distributed throughout.

This tunnel, where it branched off from the cavern, was completely filled up, and bones were very plentiful in it, except in the lowest deposit, which was found to be similar to that at the same level in the main cavern. Adjoining the entrance to this tunnel another branch-tunnel was discovered which was completely hidden under the surface-loam, &c. This tunnel proved to be the most productive in remains, and it was probably the most important of the tunnels examined. It is perfectly certain that it had never been disturbed by man since the deposits were accumulated in it, and the evidence obtained seems to point unmistakably to the conclusion that the bones, which occurred plentifully in it from the base to the roof, must have been carried into it from some other part of the cavern by water-action; or that a reassortment of the materials previously in the tunnel had taken place by water-action, and at the same time that sands and gravels

like those to be seen at this horizon in the valley at present, were forced in through the mouth of the cavern to be mixed up with the cave-earth and bones. The floor of this tunnel is several feet higher than that of the main cavern D, and the deposits in it, from the floor to the roof, consisted more or less of similar materials (see fig. 7, sect. 3). In some places they were almost entirely sands or sandy gravels, but as the excavations extended towards the opening B, they became more clayey. Bones were found in great abundance, many of large size being in contact with the roof, and others forced into small fissures. This tunnel with the communicating channel to B is over 50 feet in length, but only some 30 feet of it contained Pleistocene remains. Between that part and the opening B, the tunnel diminishes much in size, being little more than an irregular fissure-like communication. A reddish loam nearly filled this, and some bones of recent animals occurred in it near the opening B. The true tunnel may be said to terminate at the point where the Pleistocene remains disappeared, and the opening from there onwards is at a higher level. The bones in this cavern had

Fig. 6.—*Flint Lance-head from Ffynnon Beuno Cave.* (Reduced one third.)



A. Upper view.
B. Side view.

Fig. 7.—*Section 3, of West Tunnel, Ffynnon Beuno Cave.*



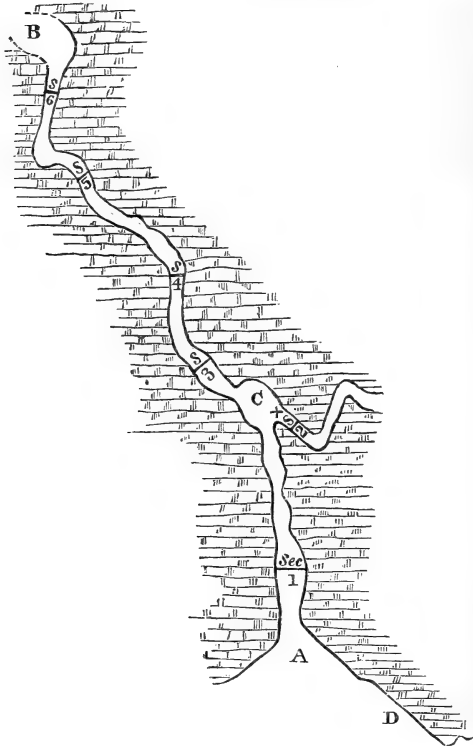
Filled with sand and clay with pebbles, containing bones (*Pleistocene*) in great abundance throughout. Not disturbed by man.

been freely gnawed, being in the condition generally of those which have been conveyed into dens by beasts of prey. Coprolites of *Hyænas* were also found, though not in great abundance. Most of

the bones were submitted to Mr. W. Davies, F.G.S., of the British Museum, for examination, and he has kindly favoured me with the appended note upon them (p. 17). Prof. Boyd Dawkins was also good enough to examine and name a considerable number at Mr. Luxmoore's house.

Some of the bones show in their fracture that it must have been the work of man, and we also discovered some showing distinct

Fig. 8.—Ground-plan of *Cae Gwynn Cave*.
(Scale, 35 feet to 1 inch.)



- | | |
|-------------------------------------|--|
| A. Entrance. | C. Chamber explored in 1884. |
| B. Chamber not completely explored. | D. Probable position of original entrance. |

+ Position of flint scraper, fig. 9.

indications of having been worked. One of these has a sharply defined hole in it as if intended to be suspended. The flint implements also prove that man must have occupied this area during the time the Mammoth, Woolly Rhinoceros, &c. roamed about the plains, and when portions of their carcasses in a fresh condition were being conveyed by beasts of prey into the cavern. The flint implements, according to Dr. J. Evans, who has kindly examined them, are of the type of the wrought flakes found in Kent's Cavern. A rather

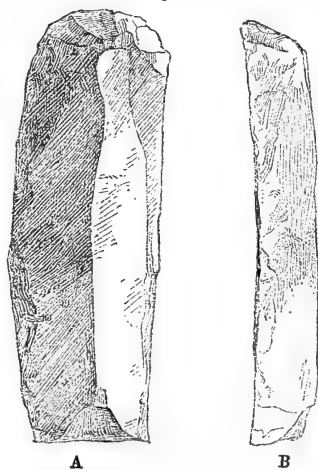
finely wrought lanceolate blade, he says, greatly resembles the one, found in Kent's Cavern, which is figured at page 450 of his 'Ancient Stone Implements,' 1872. Another seems also to be of a similar type. Others appear to have been scrapers, but are not perfect. All show indications of having been used, and they have now a white porcellanous appearance. A large round pebble of diabase was also found in this cavern, and there is every reason to suppose that it must have been conveyed into it for use by man. At one point there is a depression in it as if produced by a blow, and from this there are several radiating fractures, the result of the same force, but widened since by infiltrations.

CAE GWYN CAVE.

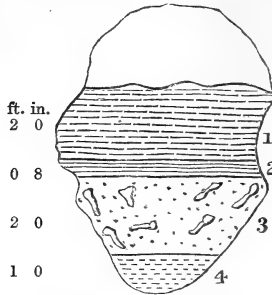
When I first crept into this cavern, in August 1884, the entrance was almost closed up by a heap of débris. A portion of the cavern had evidently been quarried away at some time, and I believe the original entrance must have been at least 25 feet more forward in the ravine. A brecciated, nearly vertical cliff-face remains, which probably shows the direction of the cavern, as also of a line of fracture. Beyond the débris for some distance into the cavern, there was a space between the loam and the roof of from $2\frac{1}{2}$ to 4 feet. We thought it best to make a trial at a small chamber (C, fig. 8) which we reached at about 45 feet from the actual entrance. Here we discovered, under the loam and some laminated clay, bones belonging to Rhinoceros, Horse, Reindeer, and Red Deer. We also found a small, well-worked flint scraper (fig. 9), stated by Dr. Evans to resemble some found in the French caves of the Reindeer period. This is not so porcellanous in appearance as those found in the Ffynnon Beuno Cave, and retains in part the natural colour. No further attempts to examine this cavern were then made, and the owner, E. Morgan, Esq., very kindly offered to close it up until we were able to begin our explorations this year.

Before commencing the work, some time had to be expended in clearing away the débris which blocked up the entrance, so as to give a free passage for the wheelbarrows. The deposits between the entrance and chamber C are fairly indicated in fig. 10 (sect. 1). The loam (1) varied from 2 to 3 feet in thickness, and contained bones only of recent animals. The underlying laminated clay (2) was only a few inches thick in some places, where disturbed

Fig. 9.—*Flint Scraper from
Cae Gwyn Cave.*



A. Upper view.
B. Side view.

Fig. 10.—Section 1 in *Cae Gwynn Cave*.

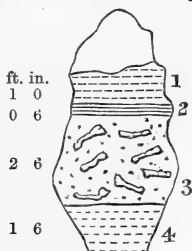
Explanation of figs. 10-15.

1. Reddish loam disturbed by burrowing animals and containing a few bones of recent animals.
2. Laminated clay containing, in places, thin ferruginous and stalagmitic bands.
3. Sandy clay with pebbles, containing bones (*Pleistocene*) and, in one place, a flint scraper (fig. 9), also large fragments of stalactites and of stalagmite.
4. Gravel consisting mainly of local materials.

by burrowing animals, but at other points it formed a compact band of over a foot in thickness. Under this was found the sandy clay with boulders (3), which contained here and throughout the cavern the *Pleistocene* remains. A varying thickness of a gravelly material (4) was found underlying the deposit 3, but this in some places in this part of the cavern was almost entirely absent. In the narrower parts of the cavern, between sect. 1 and chamber C, there were many large masses of limestone, and these had to be blasted before they could be removed. Very large masses also extended some distance into the chamber. These, I supposed last year, might possibly have formed part of the floor, but on blasting they were all found to be loose blocks with gravelly material under them. The section in this chamber showed, 1, a fine red loam from 1 to 2 feet in thickness, burrowed by rabbits and containing a few recent bones; 2, a band of laminated clay from 6 to 8 inches in thickness, containing ferruginous and stalagmitic layers; 3, a reddish clayey earth in some parts sandy, and with pebbles of felsite, granite, gneiss, quartz, quartzites, sandstones, and of local rocks. Angular fragments of stalagmite were also found in this deposit. The animal remains in it belonged to Lion, Hyæna, Bear, Red Deer, Reindeer, Horse, and Rhinoceros. The largest number of the remains obtained from this cavern were found in this chamber; but they did not occur here in horizontal layers, but in inclined and evidently disturbed positions. It is perfectly clear that they had not been disturbed by man but by water-action, and probably at different times, as bones containing clean sand in their hollows had been encased afterwards in a clayey deposit. The conditions so clearly seen in this chamber prevailed throughout the whole of the cavern, and the evidences of water-action were recognizable at all points. The order in which the deposits occurred here was also maintained in all parts examined, but occasionally it was some-

what modified by accidental circumstances, as in the places where there was much drip or where burrowing animals had greatly disturbed the earth. Under the deposit containing the Pleistocene remains was a gravelly material mainly made up of fragments from local rocks and a few small quartz pebbles, but no animal remains occurred in it. The flint scraper already referred to was discovered in this chamber in our trial examination last year, and we had hoped that a more thorough search and the removal of all the deposits from it to the local drift at the bottom would have yielded some additional implements, but unfortunately nothing further to show human occupation was discovered in this chamber, unless it is indicated by the few doubtfully calcined bones and antlers found in it. A narrow tunnel which turns sharply to the right from this chamber was cleared out to a distance of about 16 feet, its further exploration being postponed until next year. The deposits in this tunnel were like those in other parts of the cavern, but they were much more moist, on account of a rather free drip, and the divisions in the deposits were consequently less marked. The bones, however, occurred here at about the same horizon as in other parts, but they were not at all plentiful. Fig. 11 (sect. 2) shows the thickness of the deposits near the commencement of this tunnel.

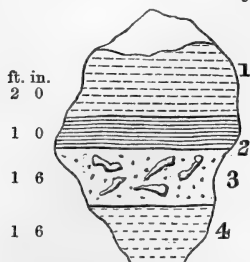
Fig. 11.—Section 2 in side tunnel of Cae Gwynn Cave.



For Explanation, see page 12.

The main tunnel was cleared out, with the exception of the deepest deposit, to a distance of over 150 feet from the entrance, and figs. 12-15 show the thicknesses found at various points. Beyond the

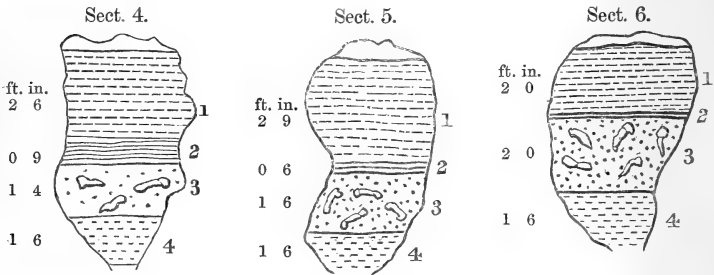
Fig. 12.—Section 3 in Cae Gwynn Cave.



For Explanation, see page 12.

part indicated in fig. 12 the cavern was almost completely filled up to the roof. The laminated band was most marked and perhaps thickest in the wide part of the tunnel shown in fig. 12, and it diminished in its compactness, though it was still well defined as the explorations extended inwards. The bones occurred throughout at the same general horizon, but in no part were they very plentiful. Very large angular masses of stalagmite and broken stalactites occurred at various points in the upper part of the deposits containing the remains, sometimes lying horizontally but often tilted, like the bones, at a high angle. The last chamber reached in this cavern (B, fig. 8) has not been fully examined, and as its roof has partially fallen in, it will have to be shored up before the explorations can be proceeded with in that direction. It is possible that a line of fissure has been reached, but this is not clear yet. The cavern up to this point is a true tunnel cavern, with well-smoothed roof and sides. It has, as may be readily seen by referring to the plan (fig. 8), been formed

Figs. 13-15.—Sections 4-6 in *Cae Gywnn Cave*.



For Explanations, see page 12.

along lines of joints in the limestone, pointing mainly N. and N.W. There are but a few small stalactites and only a very little stalagmite now forming in this cavern, and, except in the tunnel to the right of chamber C, there is comparatively little drip. Compared with the great abundance found in the Ffynnon Beuno Cavern the bones may be said to have been very scarce, but those found were certainly, on the whole, in a much more perfect condition than in the Ffynnon Beuno Cavern. Many of the long bones were quite intact, though others were gnawed in the usual way. That it must have been occupied, for a time at least, by Hyænas is proved by their coprolites being found in it.

Among the remains discovered in these two caverns there were over 80 jaws belonging to various animals, and more than 1300 loose teeth, including about 400 Rhinoceros-, 15 Mammoth-, 180 Hyæna-, and 500 Horse-teeth. Other bones and fragments of bones occurred also in very great abundance.

CONCLUSIONS.

These researches have, I think, furnished abundant evidence to show that the caverns had been occupied by Hyænas and possibly

by other beasts of prey as dens, into which portions of carcasses of various animals were conveyed in Pleistocene times. The animals were those usually found in the bone-caverns of this age, in this country, and so far no new species have been added to those already known to be common to these caverns. The very great abundance of some animals, such as the Rhinoceros, Horse, and Reindeer, and the frequent presence of bones belonging to young animals prove that the plain of the Vale of Clwyd, with that extending northward under the Irish Sea, must have formed a favourite feeding-ground even at that time. The evidence furnished by the flint implements and broken bones that man was contemporary with these animals, is useful in confirmation of discoveries in other caverns. The facts, perhaps, of greatest importance made out during these researches are those which bear on some questions of physical geology in regard to this area, which have hitherto been shrouded more or less in doubt. The views on the physical conditions in Pleistocene times of the areas in North Wales in which these and the other bone-caverns occur, so ably put forward by Sir A. Ramsay, are, in my opinion, strongly supported by the results obtained in our explorations, and it appears to me very difficult to account for the facts observed in any other way than by accepting his general conclusions. The ravine in which the caverns occur must have been scooped out previous to the deposition in it of the glacial sands and Boulder-clays. These sands and clays, there seems good evidence to show, must have filled up the ravine to a height above the entrances to the caverns, and such deposits are now found in some parts to completely fill up the caverns. How, then, did these sands and clays get into the caverns? Were they forced in through the entrances by marine action, or by a glacier filling the valley? Or were they conveyed in subsequently to the deposition of the Boulder-clay in the valley and surrounding area? The position of the caverns, as shown in the sketch (fig. 1), in an escarpment of limestone at the end of a ridge of these rocks, with a sharp fall on either side, prohibits the idea that the material could have been washed in from the higher ground, if the latter had anything like its present configuration. Moreover there is scarcely any deposit now visible upon the limestone ridge, and there is no certainty that any great thickness of such a clay as that now found in the caverns ever was deposited there. Of course I do not maintain that this was not the case, but there is no evidence at present to prove that it was so. The general position of the bones and the condition of the deposits in some of the tunnels seem to me to indicate clearly that the force which broke up the stalagmite floor, in some places from 10 to 12 inches in thickness, and stalactites from 6 to 8 inches across—thrust many of the large and heavy bones into fissures high up in the cavern and placed them at all angles in the deposits—must have acted from the entrance inwards; and the only forces which seem to meet these conditions are marine action, or those accompanying the passage of a glacier down the ravine. My own opinion, after considering all the evidence obtained, is rather in favour of the former than of the latter cause. The following

seem to me, from a study of the deposits, to be some of the changes indicated. The lowest deposits in the caverns, consisting almost entirely of local materials, must have been introduced by a river which flowed in the valley at a very much higher level than does the little stream at present. As the valley was being excavated, and the caverns were above the reach of floods, Hyænas and other beasts of prey occupied them, and conveyed the remains of other animals into them. Man also must have been present at some part of this period. Gradually the land became depressed, and the animals disappeared, stalagmite was formed in the caverns, and the sea at last entered them, filling them up with sands and pebbles, and burying also the remains not washed out. Floating ice deposited in this sea the fragments of rocks derived from northern sources, and these became mixed with local rocks and clays brought down from surrounding areas. The greater part of the Boulder-clay in the Vale of Clwyd was probably deposited as the land was being raised out of this Mid-Glacial sea. During the process of elevation the caverns became again disturbed by marine action, and the upper fine reddish loam and the laminated clays were deposited. The following stages may in that manner be accounted for, and I know of no other influences which offer better means for their interpretation: A. The infilling of the caverns by local gravels. B. The occupation of the caverns by beasts of prey and by man. C. The formation of the stalagmite. D. The breaking up of the stalagmite and the introduction of the marine sands and pebbles. E. The deposition of the laminated clay, and of the reddish loam. It seems to me impossible to avoid the conclusion that these caverns must have been submerged and afterwards elevated to their present height of about 400 feet above the level of the sea, since they were occupied by Palæolithic man and the Pleistocene animals.

NOTE (Dec. 19th).—In arriving at the foregoing conclusions I endeavoured to weigh carefully all evidence tending in any way towards showing the possibility that the materials in the caverns might have been introduced by streams in Post-Glacial times. The evidence, however, seemed to me so much stronger in favour of submergence that I felt compelled to assign the effects to that cause rather than to influxes of water either from the valley or the land above. It must be granted by all that at the close of the so-called Glacial Epoch, or, it may be said, of the last great submergence, the ravine must have been filled up by Boulder-clay to above the level of the caverns, and that the caverns must have been in existence before the clay was deposited. What changes, therefore, would be necessary to produce the effects observed if the occupation of the caverns by the Hyænas was subsequent to the deposition of the Upper Boulder-clay? The upper cavern would have to be uncovered at a much earlier period than the lower. An excavation of 22 feet would then have to be made before the lower one would be exposed, in a valley over 500 feet wide at that point, by a stream draining but a very limited area, the highest land drained by it being only about 800 feet above sea-level. Each cavern would

have to be cleared out to a definite level and then occupied for a prolonged period by Hyænas. It is clear that during the whole of the period of occupation there were no great influxes of water, and moreover, that there was a further period during which the stalagmite was formed. From some unexplained cause, after this long time of rest and presumably after the valley had been much further deepened by gradual excavation, the caverns were subject to great influxes of water sufficiently violent to break up the thick stalagmite floor, to mix up and force the materials into the inner recesses and to completely fill up all parts of the caverns. If this water was merely the result of ordinary subaerial influences, it seems impossible to conceive that the upper cavern could be invaded by it at the same time as the lower; and yet it had the effect either of preventing the caverns being occupied afterwards by the Hyænas, or it was sufficiently powerful to drive them away from the area. Submergence would do this, but hardly so any temporary local causes.

Note on the Animal Remains. By W. DAVIES, Esq., F.G.S., of the British Museum (Natural History).

The animal remains found in both caves comprise teeth and bones of 11 genera and 16 species, as shown by the annexed list:—

Lion (<i>Felis leo</i> , var. <i>spelæa</i>).	Bovine (<i>Bos</i> ? <i>Bison</i> ?).
Wild Cat (<i>F. catus ferus</i>).	Great Irish Deer (<i>Cervus giganteus</i>).
Spotted Hyæna (<i>H. crocuta</i> , var. <i>spelæa</i>).	Red Deer (<i>Cervus elaphus</i>).
Wolf (<i>Canis lupus</i>).	Roebuck (<i>C. capreolus</i>).
Fox (<i>C. vulpes</i>).	Reindeer (<i>C. tarandus</i>).
Bear (<i>Ursus</i> , sp.).	Horse (<i>Equus caballus</i>).
Badger (<i>Meles taxus</i>).	Woolly Rhinoceros (<i>R. tichorhinus</i>).
Wild Boar (<i>Sus scrofa</i>).	Mammoth (<i>Elephas primigenius</i>).

Of the animals here enumerated, three are extinct, viz. the Irish Deer, Woolly Rhinoceros, and the Mammoth. The Spelæan Lion and Hyæna were considered by Goldfuss and the older naturalists to be also extinct species; but later investigations show that their remains are undistinguishable from bones and teeth of the existing Lion * and the Spotted Hyæna † respectively. Other species now extinct in Britain are the Wolf, Bear, Wild Boar, and Reindeer, also the Wild Ox or Bison.

With regard to numbers, the teeth and bones of the Horse, Rhinoceros, Hyæna, and Reindeer are respectively the most numerous in the order here presented. That the Hyænas for a long period had entire possession of the caves is proved by the paucity of the remains of the Bear, another cave-haunting animal, thus showing that there had been no joint or alternate occupation by these animals as in some recorded instances.

* Sanford and Dawkins, "Pleistocene Mammalia," Mon. Pal. Soc. 1866, pp. 1-4.

† Dawkins, Nat. Hist. Rev. 1865, p. 95.

The state of preservation of the bones, apart from the imbedding matrix, resembles that of similar remains from other caves in limestone rocks, and inhabited by Hyænas. Few are entire; many of the limb-bones have their softer ends gnawed away, leaving the hard and denser bone of the shafts still bearing the marks of teeth. Others appear to have been fractured both longitudinally and transversely by some force when the bone was fresh, as if for the extraction of the marrow; and, again, a few crushed specimens, by some peculiar disintegration, show very distinctly the lamellar structure of the bone.

The remains of the Carnivora, excluding the Hyæna, are comparatively few. The Lion is represented by 12 canines, and the Wild Cat by a few limb-bones; the remains of the Bear, Wolf, and Fox are not respectively numerous; whilst those of the Hyæna are abundant. They consist of bones and over 200 specimens of jaws and detached teeth, a few being milk-teeth. The jaws are all more or less imperfect, and several bear traces of having been gnawed by the hungry survivors. The remains of the Wild Boar are few; chiefly teeth and a mandibular ramus of a young pig containing the milk-molars. Of the Irish Deer no portions of the antlers were discovered, but many detached teeth from the upper and lower jaws. Excluding the antlers, the remains that could with certainty be referred to the Red Deer are few. Of the antlers there are several fragments, some nearly as large as the antlers from Kent's Hole, described by Sir Richard Owen as *Strongyloceros spelæus**, on account of their large size. There is also an unshed antler ("Pricket") of a Stag of the second year. Of the Roebuck, we can only record a tibia and a few phalanges, all from the lower cave; but, as in many other caverns, the remains of the Reindeer are very numerous, chiefly portions of antlers, referable to individuals of all ages and many varieties of form, also portions of jaws, detached teeth, and bones. Both sexes of the Reindeer bear antlers which, in some measure, accounts for their greater relative proportion to the skeletal remains, as compared with those of the Red Deer. But there can be little doubt that the Hyænas carried into their retreats many that had been shed.

Most, if not all of our British caves contain remains of the Horse, and ours do not form an exception, for teeth and bones are the most abundant in each case; and they also show that there were great individual variations as to size in the herds that roamed in the district. As regards their structure the teeth are undistinguishable from those of the existing Horse.

The next in point of number are the teeth and bones of the Woolly Rhinoceros, of which over 400 teeth were exhumed; they embrace many examples of the deciduous teeth, some so young that the ridges are scarcely abraded, and others in which the crowns are nearly worn away. This also applies to the teeth of the adults. The teeth and bones agree in size with the remains of the same species found in our brick-earths and gravels. The Mammoth is

* Owen, Brit. Foss. Mamm. p. 469.

also represented by milk-molars, fragments of other teeth, a last upper true molar, and a few bones.

The Mammoth, Rhinoceros, and Reindeer were true representatives of a cold or Arctic climate.

DISCUSSION.

Dr. EVANS bore testimony to the great interest and value of Dr. Hicks's discoveries, but with respect to his conclusions he had very considerable difficulty in accepting them. He did not think that it was necessary to invoke the great submergence for which Dr. Hicks argued. He believed that the tunnel-caves had been in existence before the period of the deposition of the Boulder-clay. After the re-emergence of the country the caves appear to have been occupied by Hyænas, though influxes of water carrying cave-earth occasionally took place. The pressure of such accumulated water might also lead to the breaking up and promiscuous mingling of the contents of the caverns.

Prof. BOYD DAWKINS shared the doubts of the previous speaker as to the justice of the author's conclusions. Similar phenomena to those described occur in caves like Wookey Hole, and even in caves in the immediate neighbourhood of those described. He believed that the occasional flooding of the caves while they were inhabited by the Hyænas would fully account for all the phenomena described. He did not accept the laminated clay as a proof of glacial conditions. He did not believe that the breaking up and mingling of the deposits could be effected either by glaciers or by the action of waves. The implements made of flint derived from the glacial deposits found in Pont Newydd Cave on the opposite side of the valley, prove that Palæolithic man was in the district subsequently to the Glacial period. He admitted the great difficulty of accounting for all the phenomena presented in some of these cases.

The AUTHOR said that the theory suggested by the speakers in the discussion had not met any of the difficulties raised by the facts which he had adduced against believing that currents of water carried the Boulder-clay into the caves. He could not see how water, entering the tunnels in the manner suggested, could possibly produce the results observed, subsequently to the scooping of the valley and the prolonged occupation of the caverns by Hyænas, except by submergence. That the area had been subjected to great submergence is granted by all; the question in dispute is as to whether or not a submergence had taken place since the caverns had been occupied by Hyænas. The views held by himself agreed in the main with those of Sir Andrew Ramsay, Mr. Mackintosh, and the late Mr. Trimmer.

3. *On the Occurrence of the Crocodilian Genus Tomistoma in the Miocene of the Maltese Islands.* By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read November 18, 1885.)

[PLATE II.]

IN the collection of the British Museum there is the terminal 13 inches of the rostrum of a large Crocodilian, from the Miocene of Malta, to which Prof. Sir R. Owen has applied the name *Melitosaurus champsoides*, but of which, so far as I am aware, no description has ever been published. The name is, therefore, really a manuscript one; but since it has been quoted by Mr. J. W. Hulke* and the late Prof. Leith-Adams †, and the type specimen referred to as affording grounds for specifically distinguishing another specimen, it seems advisable to take (with the proviso noted below) Sir R. Owen's specific name as dating from the first quotation.

The specimen, which is figured on a reduced scale in the accompanying plate (Pl. II. figs. 1, 2), shows the cranial and mandibular portions of the rostrum. The former has lost all the teeth with the exception of one, but shows eight dental alveoli on the right side; while the latter shows six teeth *in situ* in the left ramus: the whole of the premaxillæ, and the anterior narial aperture, together with the anterior part of the nasals and maxillæ, are preserved. It will perhaps suffice to say that the specimen is nearly double the size of an adult skull of the existing *Tomistoma Schlegeli* (Strauch), and that it agrees with the latter in every essential respect. Thus the rostrum is extremely long and narrow; the first and fourth mandibular teeth are larger than the others, and are received into notches in the cranium; the third premaxillary tooth is large, and the fourth very small; while the premaxillæ themselves are not terminally expanded, are long and narrow, and articulate with the still narrower nasals. Apart, indeed, from its superior size, almost the only noticeable difference of the fossil from the recent *Tomistoma* consists in the circumstance that the extremity of the premaxillæ is more shelving, and that the teeth are perhaps relatively larger, and their fore-and-aft cutting-edges rather less sharp; it also differs, however, in having five teeth in the premaxilla, the additional tooth being, as in *Gharialis (Gavialis) gangeticus*, interpolated between the proper first and second teeth. Since this additional tooth is very variable in *Crocodylus*, its presence in the present form can scarcely be considered more than a specific character; and as there are no other characters which can be regarded as of generic value, the term *Melitosaurus* appears unnecessary, and the specimen may be referred to the existing genus under the name of *Tomistoma champsoides* (Owen).

* Quart. Journ. Geol. Soc. vol. xxvii. pp. 31, 32 (1871).

† *Ibid.* vol. xxxv. p. 527 (1879).

From the reputed Miocene of the neighbouring island of Gozo another Crocodilian has been described by Mr. J. W. Hulke* under the name of *Crocodylus gaudensis*, which is said to differ from *Tomistoma champsoides* by its smaller size, more slender and more sharply pointed teeth, and the structure of the dental enamel. In his description of the skull of this species, Mr. Hulke says that it agrees with *Tomistoma Schlegeli*† in the long rostrum, elongated premaxillæ (which articulate with the long slender nasals), and in the entrance into the mandibular symphysis of the splenial element. The latter character at once forbids the reference of the species to *Crocodylus*, and as the specimen agrees with *Tomistoma* in essential characters (although differing from *T. Schlegeli* in several details which do not appear of more than specific value) it may be pretty safely referred to that genus under the name of *T. gaudense* (Hulke).

In a recently published paper, Messrs. Toula and Kail‡ have described a Crocodilian cranium from the apparently Miocene strata of Eggenburg in Lower Austria, which they propose should be provisionally known as *Gavialosuchus eggenburgensis*. This specimen agrees very closely with *T. Schlegeli* in the number of the teeth and in the general contour of the rostrum and the relations of the nasals to the premaxillæ; although differing by the presence of five premaxillary teeth, and the eversion of the anterior border of the orbit. In respect to the number of premaxillary teeth the Austrian form agrees with *T. champsoides*, and the conclusion as to the value of this character in the one case will likewise apply to the other. The eversion or non-eversion of the anterior border of the orbit appears to the writer to be also a character which should not be regarded as of generic importance, as he has found it to be very variable in the fossil Gharialoids of the Siwalik Hills of India§; and it accordingly seems that the Austrian form may be included in *Tomistoma*. The two peculiar features of the Austrian species (at least one of which occurs in *T. champsoides*) indicate a decided approach towards *Gharialis* (*Gavialis*). Finally, the question arises whether this *T. eggenburgense* may not be specifically identical with the Maltese *T. champsoides*; but it seems impossible to decide the question until the former shall have been figured. If the two be identical, the specific name applied by Messrs. Toula and Kail has the right of priority, since Owen's species has not hitherto been defined.

The genus *Tomistoma* is represented at the present day solely by *T. Schlegeli* of Borneo, and the three forms noticed above are the only fossil species with which I am acquainted. The occurrence of the genus in the Miocene of the Maltese Islands and Austria

* Quart. Journ. Geol. Soc. vol. xxvii. pp. 30-32 (1871).

† Mr. Hulke employs Huxley's generic term *Rhynchosuchus*, which is of later date than *Tomistoma*.

‡ Anzeig. k. Ak. Wiss. Wien, 1885, pp. 107-109; Ann. & Mag. Nat. Hist. ser. 5, vol. xvi. p. 236.

§ See Palæontologia Indica (Mem. Geol. Surv. Ind.), ser. 10, vol. iii. part 7 (1886).

affords one more instance of the survival of Middle and Upper Tertiary European genera in the oriental region.

P.S. (Jan. 20, 1886).—Since the preceding was in type I have seen the full description and figures* of the so-called *Gavialosuchus eggenburgensis*. This fully confirms my opinion that this form is not generically distinct from *Tomistoma*; the anterior extremity of the premaxillæ of the Austrian specimen is unfortunately imperfect, but from the characters of the remaining portion it is not improbable that this form is specifically distinct from *T. champsoides*.

EXPLANATION OF PLATE II. FIGS. 1, 2.

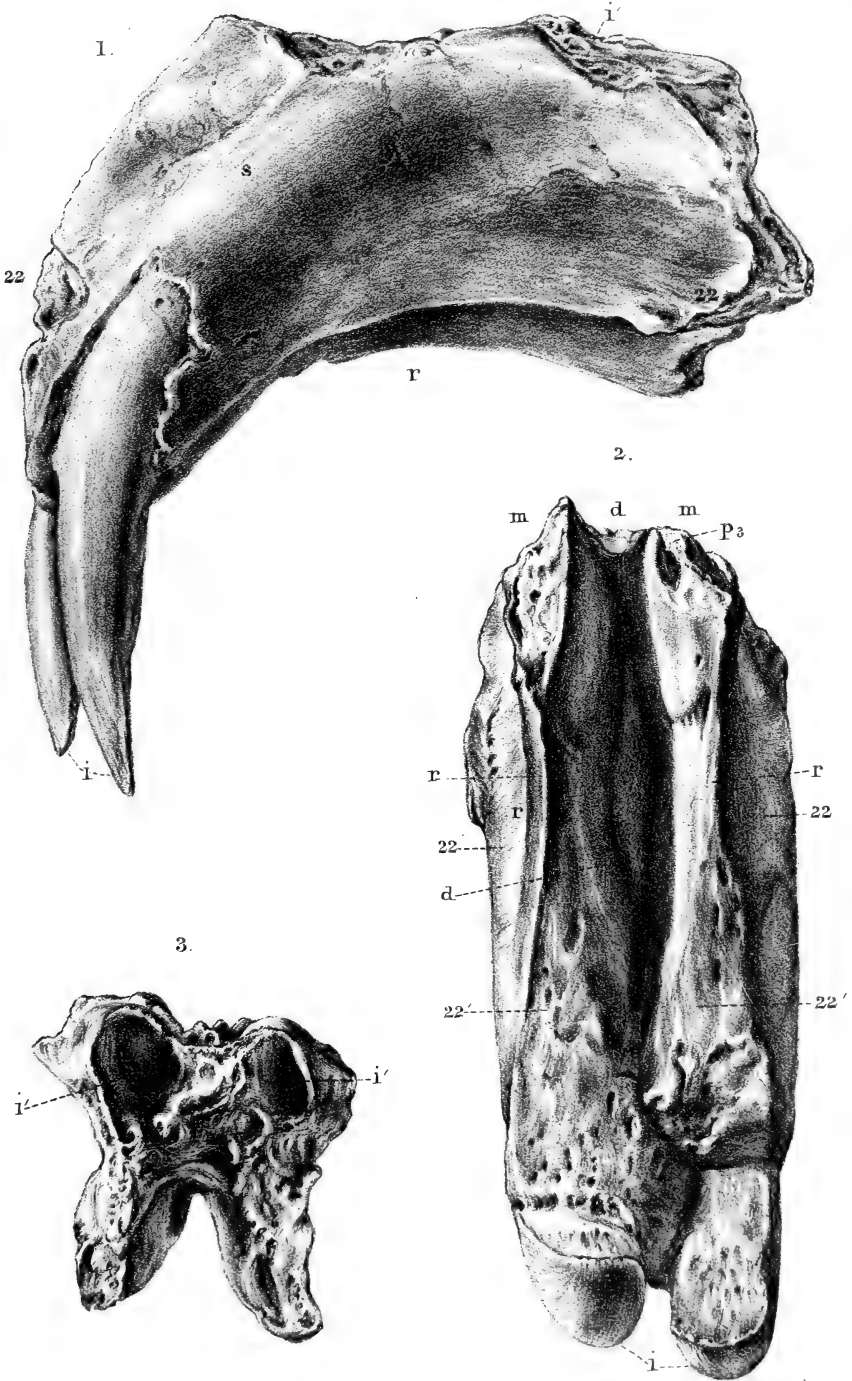
Tomistoma champsoides (Owen); fig. 1. Anterior portion of the rostrum, viewed from the facial aspect; fig. 2. Anterior part of the left ramus of the mandible, viewed from the outer aspect. One half natural size.

DISCUSSION.

Prof. BOYD DAWKINS remarked on the interest attaching to the occurrence of oriental forms in Miocene beds in the European region, such as Eastern deer of *Rusa* type, muntjac, tapir, &c.

Mr. BLANFORD pointed out that the particular interest in this case was due to a genus once spread through several parts of Europe being now confined to one oriental island, in the purely tropical Malay subregion of the oriental region. Some other European Miocene forms are also now peculiar to the same Malay subregion.

* Toulou and Kail, Denkschr. k. Ak. Wiss. Wien, vol. 1. pt. 2, pp. 229-356, pls. i.-iii. (1885).



Mintern Bros. imp.

PHASCOLOMYS CURVIROSTRIS

4. DESCRIPTION of the CRANIUM of a new Species of ERINACEUS from the UPPER MIOCENE of GENINGEN. By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read November 18, 1885.)

[PLATE II.]

AMONG the collection of fossil remains purchased in 1871 by the British Museum from the executors of the late Professor van Breda, of Haarlem, was a small slab of limestone from the Upper Miocene of Geningen, Switzerland, containing the ventral half of a small mammalian cranium, of which only the dorsal aspect was exposed. At the time of writing part i. of the 'Catalogue of Fossil Mammalia in the British Museum' (1885), I was unable to come to any conclusion as to the affinity of the specimen in its then condition, and it was therefore not entered. Shortly afterwards, however, Mr. W. Davies, F.G.S., of the British Museum, thought that the specimen might be "developed;" and by careful chiselling under his direction the palatal surface was cleared, and revealed the whole of the dentition of a species of *Erinaceus* in a most perfect state of preservation.

Before discussing the affinities of the fossil form, it may be as well to give a brief notice of the extent and distribution of the genus. The dental formula is I. $\frac{3}{2}$, C. $\frac{1}{1}$, Pm. $\frac{3}{2}$, M. $\frac{3}{3}$; and as Dr. Dobson* considers that the three upper premolars are respectively homologous with the last three teeth of the typical series of four, they will be termed pm. 2, pm. 3, pm. 4 †.

At the present day nineteen species are recognized by Dr. Dobson ‡, which are distributed throughout Europe, Africa, and the greater part of Asia. Of these, *Erinaceus europæus* (which is considerably larger than the majority of the other species) is an aberrant form, differing from all the others in that the third upper incisor and the second upper premolar have each but a single (instead of a double) root, and exhibit marked peculiarities in the form of their crowns; in some instances the two roots of the upper canine have coalesced § in this species. Two of the Indian species (*E. micropus* and *E. pictus*) are further distinguished by the minute size, simple structure, position, and caducous character of the upper pm. 3; while the former is, again, differentiated by the absence of the jugal element of the zygomatic arch ||. The African *E. albiventris*, on account of the absence of the hallux, has been referred by some zoologists (in my own opinion unnecessarily) to a separate genus.

Turning to fossil forms, five species are recorded by Gervais in the

* Proc. Zool. Soc. 1881, p. 403.

† By many writers these three teeth are termed first, second, and third premolars.

‡ Encyclopædia Britannica, 9th ed. vol. xv. p. 402 (1883).

§ Vide Dobson, Proc. Zool. Soc. 1881, p. 403, fig. 10.

|| The Indian species are described by Anderson in the Journ. As. Soc. Beng. vol. xlvii. pt. 2, pp. 95-211, pls. iii., iv., v., v.A (1878).

'Zoologie et Paléontologie Françaises,' 2nd ed. p. 53, and I am unacquainted with any others. The first of these five is *E. major*, Pomel, from the Upper Pliocene of Puy-de-Dôme, which is said to be somewhat larger than *E. europæus*, and to have thicker molars and stouter limb-bones; in the absence of a figure it is, however, almost impossible to say whether this form is really entitled to specific distinction, and it can, therefore, only be regarded as a nominal species. *E. arvernensis**, from the Lower Miocene of Auvergne, is known only by the mandible, and is a small species, apparently agreeing very closely with some of the Asiatic forms. The third species, *E. sansaniensis*, Lartet †, from the Middle Miocene of Sansan, is also of small size, and is known by teeth, fragments of the mandible, and limb-bones; but it can hardly be considered more than a nominal species. The fourth species, *E. dubius*, Lartet ‡, from the same formation, is founded on a fragment of a mandible with three teeth, which, judging from the description, most probably belongs to the genus *Plesiosorex* §. The fifth species, *E. nanus*, Aymard, from the Lower Miocene of Ronzon, is a very small form, which was subsequently made the type of a new genus *Tetracus* ||. Finally, Lartet ¶ mentions fragments from the Middle Miocene of Sansan, which indicate a species equal in size to *E. europæus*.

Reverting now to the fossil, it may be observed that it indicates a species nearly equal in size to *E. europæus*, the length of the cranium from the foramen magnum being 0·048 m. in the former, and 0·052 m. in a full-sized example of the latter; the second incisor bears nearly the same proportion to the third as obtains in *E. europæus*, but the first incisor is relatively smaller than in that species; there is a diastema between the third incisor and the canine, and each of these teeth appears to be inserted by two roots. The second premolar has two roots**, and there is no diastema between it and pm. 3, the latter tooth being large and complex; the second true molar is relatively smaller in comparison with m. 1 than in *E. europæus*. The zygomatic arch is complete, but the state of preservation of the hinder part of the palate does not admit of close comparison with recent skulls.

The presence of two roots to pm. 2, and probably to i. 3, distinguishes the specimen from *E. europæus*; and a comparison with the fine series of skulls in the British Museum has shown that it cannot apparently be referred to any other existing species. It comes, on the whole, nearer to the North African *E. algirus* than to any other species, but differs by the relatively smaller m. 2 and m. 3, and the relative proportions of the incisors.

Of the named fossil species, the only one which could possibly be

* See Cat. Foss. Mamm. Brit. Mus. pt. i. pp. 17, 18 (1885).

† Notice sur la Colline de Sansan, p. 12 (1851).

‡ *Loc. cit.*

§ See Cat. Foss. Mamm. Brit. Mus. pt. i. p. 19 (1885).

|| See Filhol, Ann. Sci. Géol. vol. xii. art. 3, pp. 8-14 (1881, vol. dated 1882). The question is discussed whether this genus may not be identical with one of those described by Pomel.

¶ *Op. cit.* p. 13.

** In examining this tooth the crown broke off and revealed the two fangs.

identical with the present form would be *E. major*; but, as already mentioned, it is impossible to consider that species as more than a nominal one; it is, however, quite probable that the unnamed large species from Sansan may be identical.

As the Öeningen specimen cannot, therefore, be identified with any named form, it may be regarded as a new species, for which the name *Erinaceus öeningensis* is proposed. This species may be defined as agreeing nearly in size and the number of roots to the upper teeth with *E. algirus*, but distinguished by the proportionate size of the incisors and true molars. It is somewhat difficult to determine whether the characteristic features of the dentition of *E. europæus* indicate a higher or lower degree of specialization than that obtaining in the other existing species; but since the Öeningen species agrees in this respect with the latter group, and that group comprehends such a large number of forms, it is not improbable that the dentition of *E. europæus* is the most specialized. Considering, then, that the peculiar features of the dentition of *E. europæus* may be of comparatively recent origin, and taking into account the close general resemblance in size and structure existing between *E. öeningensis* and the larger Palæartic forms like *E. europæus* and *E. algirus*, it is not improbable that the former may be the parent stock from which one, or perhaps both, of these species were derived. The small dimensions of the Lower and Middle Miocene *E. arvernensis* and *E. sansaniensis* may, perhaps, also indicate that the parent stock of some of the smaller existing Asiatic species likewise originated in the Tertiaries of Europe.

EXPLANATION OF PLATE II. FIGS. 3, 4.

Erinaceus öeningensis, Lydekker. Cranium from the Upper Miocene of Öeningen: fig. 3, palatal aspect, natural size; fig. 4, right upper dentition, $\times 2$. British Museum (no. 42824).

DISCUSSION.

Mr. E. T. NEWTON remarked on the small differences between the lesser fossil animals of the later Tertiaries, more especially the Pliocene, and those of the present day; and while not doubting the validity of Mr. Lydekker's new species of Hedgehog, called attention to the tendency there had been, at a time when it was thought that no fossil species could be the same as a recent one, to give new names; but when recent forms were traced back in time, it was found that they extended much further than was anticipated, and some of the fossil species turned out to be identical with the recent.

Dr. WOODWARD said that this specimen, with many others, was obtained by Dr. Oswald Heer, when a student. The specimens were purchased by Dr. van Breda, and the money was used by Heer to pay his college fees.

Mr. LYDEKKER, in reply, agreed with Mr. Newton's remarks, and said that in this case he had insisted on affinities rather than differences from existing species. Still the distinctions were marked. All fossil hedgehogs came very near recent forms, and this one was closely allied to Palæartic species.

5. *On some BORINGS in KENT. A CONTRIBUTION to the DEEP-SEATED GEOLOGY of the LONDON BASIN.* By WILLIAM WHITAKER, B.A., F.G.S., Assoc. Inst. C.E. With PALÆONTOLOGICAL INFORMATION by G. SHARMAN, Esq., and E. T. NEWTON, Esq., F.G.S. (Read December 2, 1885.)

[Communicated by permission of the Director General of the Geological Survey.]

[PLATE III.]

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 4. Frindsbury, Chattenden Barracks.
 5. Boxley Grange, South of Chatham.
 6. Chartham, South of Canterbury.
 7. Dover.
 C. Geological Results of the Borings.
 D. General Remarks on the Deep-seated Geology of the London Basin.
 E. Explanation of the Map and Section.

A. INTRODUCTORY STATEMENT.

AN account of the well at the Chatham Dockyard Extension Works, to the depth of 268 feet, was given, in 1872, in the "Memoir on the Geology of the London Basin"*. Since the publication of that work the boring has been continued, through the Chalk and the Gault, to the Lower Greensand, and a second boring has been made to a little greater depth, with the unexpected result of reaching Oxford Clay.

It will be of interest therefore to give a full account of these borings, of which only short notices have yet appeared†, and to review the bearing that the result of the later one has on our knowledge of the underground formations of the London Basin.

The borings are about 210 yards westward of the Factory Basin, in what was, until the extension of the docks was made, the marsh on the southern side of the former St. Mary's Creek, that creek having also been included in the new dockyard. The surface of the ground is about ten feet above Ordnance Datum.

The earlier boring, which reached Lower Greensand at a depth of over 903 feet, being of small size, in the lower part at all events, it was resolved to put down another and larger one near by, in order to get a large amount of water from the Lower Greensand;

* 'Geological Survey Memoirs,' vol. iv. p. 459.

† Of the first boring, in the 'Guide to the Geology of London and its Neighbourhood,' ed. 3, p. 19 (1880), and of both in ed. 4 of that little work, pp. 19, 21 (1884). The later boring has also been noticed in the abstract of a paper (substantially the same as this) read to the British Association at Aberdeen, which has appeared in various journals.

and it is to the second boring that this paper chiefly refers, because of the unforeseen result.

One would have thought that Chatham was favourably placed for getting a large supply of water from the Lower Greensand, which formation has a broad outcrop only a few miles to the south. It was therefore with some surprise that one heard that, after passing through only 41 feet of sandy beds (below the Gault), a mass of clay was reached at the depth of 943 feet.

At first this clay was naturally taken to be either a very clayey development of the Sandgate Beds (an idea soon abandoned), or Atherfield Clay, or Weald Clay, this last seeming to be the most likely, as it crops out from beneath the Lower Greensand in strong force to the south*. The specimens of the clay, however, were not quite like what would be expected from Weald Clay; but no little astonishment was felt when such of the small fossils in it as could be made out were determined to belong to Oxford-Clay species.

This was first suggested by Mr. J. P. Creswick, to whom the Geological Survey is indebted for information and assistance in this subject, and who had washed some of the clay at the Admiralty Office of Works. It was fully made out by Mr. G. Sharman in August 1884, when he recognized a specimen of *Ammonites crenatus*, from a depth of 958 feet. Other specimens of Oxford-Clay species have since been found higher up, to 925 feet from the surface, and therefore we may safely include the whole of the clay (beneath the Lower Greensand) as belonging to that formation, especially as it is of much the same character throughout.

Since this paper was written (February 1885), Prof. Judd has referred to the subject†, remarking that the fossils prove that we have to do with the middle part of the Oxfordian, the zone of *Ammonites Lamberti*.

The question of the advisability of continuing the boring having been referred to me by Mr. Bristow, I reported thereon (29th November, 1884), concluding as follows:—"As a question of scientific interest, and one, probably, of great practical importance (in view of the possibility of the occurrence of Coal Measures), the continuance of the boring is highly to be desired; but as a question of getting water, it can hardly be recommended. One would expect the underground ridge of older rocks (that has been proved under London &c.) to be met with, and, perhaps, at no great further depth . . . but what formation . . . would be found seems beyond conjecture." In a later communication, again (after having been instructed to prepare a paper on the subject), I ventured to say that my own personal opinion was that the boring should be carried on, as an experimental boring (apart from the question of water-supply), and, at the same time, I suggested that if a large amount of the cores from the boring had been kept at Chatham, and were to be

* See Topley, in the discussion on Prof. Judd's paper, Quart. Journ. Geol. Soc. vol. xl. p. 763 (1884). His opinion, however, was based only on some very small specimens.

† Quart. Journ. Geol. Soc. vol. xli. pp. 526, 527.

seen, it would be well that they should be examined on the spot, and special parts selected for more detailed examination at Jermyn Street.

In accordance with this suggestion, Mr. E. T. Newton was sent to Chatham, and he has given me many useful notes, besides assisting Mr. Sharman in the determination of the fossils.

This paper originally referred to Chatham only; but, in order to make it as complete as possible, accounts of other unpublished deep borings in Kent which pass through the Chalk, have been added. The details of two of these were not received until the day on which the paper was read, and some further notes of the Dover boring have come to hand since.

B. DETAILS OF THE BORINGS.

The following account of the beds passed through in the Chatham wells has been compiled from various documents, mostly unpublished, and from the examination of specimens. To Col. Percy Smith, R.E., Director of Works at the Admiralty, the Geological Survey is indebted for a set of specimens from the second well and for information about it. In all cases words in square brackets have been inserted by myself.

1. *Chatham Dockyard Extension*.—Well No. 1. 1868–1878.

E. A. BERNAYS. Lectures on Chatham Dockyard Extension Works. Delivered at the School of Military Engineering, Chatham. For private circulation. Fol. *Chatham*: 1879. Pp. 13, 14.

Measurements from the coping-level of the new basin = $5\frac{1}{2}$ feet above high water of ordinary spring tides.

Shaft and cylinders 67 feet, the rest bored.

At a depth of 301 feet an ample supply was found; but the water was very hard and of bad quality (from infiltration from the river); it was therefore shut out. Water rose from the bottom and overflowed; it was found that it would rise to 19 feet above the ground.

The flow was at the rate of 80 gallons a minute, which continued [for some time], the water being soft and good, with a temperature of 65° .

	Thickness.	Depth.	
	ft. in.	ft. in.	
Made ground and alluvial mud	12 0	12 0	
[River Drift.] Loamy gravel	10 6	22 6	
[Thanet Beds?] Loam	3 0	25 6	
Chalk, 684 $\frac{1}{2}$ ft... {	Soft chalk	22 0	47 6
	Hard chalk	552 0	599 6
	Chalk Marl	110 6	710 0
[Gault, 193 $\frac{1}{2}$ ft.] {	Gault [clay]	191 6	901 6
	Rock [? nodules]	0 9	902 3
	Greenish sandy marl ...	0 6	902 9
	Rock [? nodules]	0 9	903 6
To [Lower] Greensand.			

Information communicated by the Dockyard authorities differs somewhat in details (to the base of the Chalk), giving the following section. In the drawing from which part of this was taken the thickness of the beds was different on opposite sides, and the measurements were therefore made along a middle line.

	Thickness.	Depth.	
	ft. in.	ft. in.	
Marsh-clay and mud.....	6 0	6 0	
River-gravel (? 9 to 12½ ft.)	11 3	17 3	
Loam [Thanet Beds]	3 9	21 0	
Chalk, 689 ft. {	Chalk (soft rubble), with a layer of flints at bottom	43 1	64 1
	Block chalk, with many layers of flints	80 3	144 4
	Hard rocky material, called "white flint"	2 9	147 1
	Chalk, with many layers of flints ...	139 1	286 2
	Hard chalk. Fissures 45 ft. deep at about 300 ft., and a layer of black flint	234 10	521 0
	Chalk [a small specimen looked like ordinary Lower Chalk]	79 0	600 0
	Chalk Marl. At the bottom the following succession:—A soft bed, 2 ft. thick, underlain by sandy loam, 1½ ft., and then hard Chalk Marl, 1 ft.	110 0	710 0

In June 1880 I saw, at the Dockyard, some of the cores that were brought up. The lowest three feet or so of the Chalk Marl was grey, with green grains, and with some small nodules (especially just above the base, which was given as 712 feet deep), differing slightly therefore from both versions of the section. The specimen showing the junction with the Gault was hardened; one part being Gault, the other Chalk.

2. Chatham Dockyard Extension.—Well No. 2 (about 20 feet from No. 1). 1880–1884.

From documents communicated by the Admiralty and from specimens.

Measurements taken from the level of the coping of the new basin, which is about 18 feet above Ordnance Datum.

Shaft 450 feet?, the rest bored.

Water found 17th August, 1880, at a depth of 902 feet. After five hours it flowed over the pipe, 3 feet above the level of the coping.

At 912 feet the water contained about 1 per cent. of sand, of which several cart-loads were pumped up. The pump, 160 feet down, lifted 300,000 gallons in 24 hours, keeping down the water to 103 feet below the level of the coping.

		Thickness in feet.	Depth in feet.
Made ground.....	about	15	15
Loamy gravel.	} ...	12	27
[? Thanet Beds]. Loam, with flints at the bottom			
Chalk, 682 ft.	Soft white chalk (Bullhead).....	9	36
	Hard white chalk, with beds of flint at intervals	116	152
	Grey chalk in layers, alternately hard and soft, with beds of flint at intervals. At a depth of 517 ft. hard greenish chalk, 16 ft. thick ...	427	579
Gault, 193 ft.	Chalk Marl	130	709
	Clay (? more sandy at top). Specimens of grey clay from 870 and 890 ft. deep	192	901
	Calcareous sandstone, with small black phos- phatic nodules and many glauconite grains...	1	902
	Sand. The beds fell in, so that their nature is a little uncertain. Specimen, from 912 ft. (from water pumped up), fine sharp sand, with glauconite grains	11	913
Lower Greensand, 41 ft. Folkestone Beds, 30 ft.	Coarse dark sand and grit, with nodules 6 ft. down. Specimens, from 913 ft., phosphatized <i>Ammonites</i> ; from 915 ft., with broken- up phosphatic nodules; from 918 ft., with waterworn phosphatic nodules. The nodules, Mr. Newton thinks, may have fallen down from the Gault	8	921
	Sandy beds with stones [nodules]. Specimens of fine sand, with glauconite grains, from 921 and 924 ft., with nodules from 927 and 928½ ft.	9	930
	Sandy beds, compact and dark. Specimens from 930 ft.	2	932
	Sandgate Beds? Compact sandy clay, with nodules of impure iron-pyrites, 7 ft. down. Specimens from 932 ft. (with nodules), 934, 936, 940, 941, and 942 of grey clayey sand or sandy clay	11	943
	Oxford Clay. Hard stiff clay, drying light-grey, with nodules [pyrites?] 4 ft. down (a specimen is of pyrites, partly crystalline, with an included piece of phosphatized <i>Ammonite</i>), and with a hardened layer 10½ ft. down. Specimens from nearly every foot (wanting 944, 946, 948, 957, 959, 961-964), with pyrites from 943 ft.; two phosphatic nodules (? fallen) from 953 ft.	22?	965?

In a drawing the thickness of the bottom clay is made only 20½ feet, and the total depth 963½; but there is a specimen from 965 feet.

Mr. Newton reports that cores from the second boring (below the 450 feet that was dug) are lying on the ground, but with no indication of the depths from which they came, although that was carefully marked when they were drawn. He adds that a diary, kept in the office at the dockyard, states that the first core was drawn from a depth of 470 feet, though it seems that only a part, if any, of this first core is now preserved; so that probably the cores now lying on the ground begin from below that depth, from which it follows that only about 240 feet of Lower Chalk is represented by them.

An examination of the cores showed, says Mr. Newton, that at a depth of about 500 feet (30 feet from the top part) an irregular nodular bed occurs, with many shells of *Inoceramus* (which seemed to belong to *I. Brongniarti* and *I. Cuvieri*). He was unable to identify the zone of *Belemnites plenus*, though many *Belemnites* were said to have been found in the Chalk, but at what depth was not known.

Low down in the Chalk Marl the following characteristic fossils were got:—*Baculites baculoides*, a fragment of a Hamite, and part of a *Pecten Beaveri*.

The Gault cores were fast disappearing, broken up by frost and then overgrown, and no trace of fossils was to be seen. No clue could be got to any horizons therefore; but, from specimens sent to the Geological Survey in 1880, the following list has been made, and the fossils seem to have been chiefly found at depths of from 855 to 882 feet.

List of Fossils from the Gault.

<i>Ammonites auritus</i> , <i>Sby.</i> — <i>Beudantii</i> , <i>Brongn.</i> — <i>rostratus</i> , <i>Sby.</i> (= <i>inflatus</i>). — <i>tuberculatus</i> , <i>Sby.</i> — <i>varicosus</i> , <i>Sby.</i> <i>Belemnites</i> (fragments). Hamites, 2 species.	<i>Rostellaria carinata</i> , <i>Mant.</i> — <i>Cucullæa carinata</i> ?, <i>Sby.</i> <i>Inoceramus concentricus</i> , <i>Park.</i> — <i>sulcatus</i> , <i>Park.</i> — <i>Serpula</i> . — <i>Cyclocyathus</i> .
Actæon. <i>Natica gaultina</i> , <i>D' Orb.</i>	

A small undeterminable Gasteropod was the only fossil found after washing specimens of the sandy clay forming the bottom part of the Lower Greensand, between the depths of 934 and 938 feet; whilst specimens from 941 and 942 feet yielded only fragments of shells. There is therefore no fossil evidence as to the age of the beds which have been classed as Lower Greensand, and it has been suggested that some few feet of the top part may be sandy beds of the Gault; but, in the absence of evidence, the only safe plan is to class the whole of these beds together.

Unless the few phosphatized *Ammonites* have fallen in, from the junction-bed with the Gault, they are, I think, in favour of the above view, although the occurrence of derived fossils (as some of these seemed to me to be) has not been noticed in the Lower Greensand of this district. The specimens are much rolled.

A specimen from the top part of the Oxford Clay yielded, on washing, fragments of bivalve shells and a minute Gasteropod; but none of these were determinable. From a depth of 945 feet downwards fossils were found in all the specimens. They are essentially the same throughout, and all very small; but they leave no doubt as to the age of the beds. It is noteworthy that of the nine species figured by G. Damon as characteristic of the Oxford Clay*,

* 'The Geology of Weymouth,' ed. 2, p. 28 (1884).

five have been found here. I may add that the pyritized Ammonites and the *Serpula vertebralis* at once reminded me of the Oxford-Clay fossils that I was accustomed to find in Bedfordshire, in my first year of Survey life, no need to say how long ago.

List of Fossils from the Oxford Clay (at depths from 945 to 965 feet). All the specimens very small and fragmentary.

Ammonites crenatus, *Brug.*
 ——— hecticus? *Rein.*
 ——— Lamberti, *Sby.*
 ——— plicatilis, *Sby.*
 ——— minute forms, possibly young.
 Belemnites. ———
 Alaria trifida. ———
 Very minute Gasteropod. ———
 Astarte. ———
 Corbula? ———
 Pecten. ———
 Crustacean claws and limbs.
 Bairdia, near to Juddiana, *Jones.*
 Serpula vertebralis, *Sby.*

Serpula, sp. ———
 Acrosalenia (?), small spine.
 Cidarid, plate and small spine.
 Pentacrinus Fisheri*, *Baily (Forbes, MS.)*? = *P. sigmariniensis.*
 ——— sp. ———
 Small turbinate coral. ———
 Cristellaria crepidula, *F. and M.*
 ——— rotulata, *Lam.* (var. with cupped centre and raised septa).
 ——— ——— (var. with smooth outside). ———
 Wood. ———

3. *Frindsbury. Whitewall Cement Works (Formby's). 1882.*

Sunk and communicated by Mr. T. Tilley.
 30 feet above high-water mark.

Bored throughout, 4 inches diameter, lined with tube.

Directly the rock was pierced water rose to the surface, throwing out a large quantity of sand and pebbles. It rose to a height of 61 feet above high-water mark. The water is bright, free from sand, and has been analyzed by Dr. Voelcker.

Yield 60 gallons a minute. In December 1885 the supply was as strong as when first tapped.

	Thickness in feet.	Depth in feet.
Chalk	618	618
[Gault, 192 ft.] { Gault clay	189½	807½
{ Rock	2½	810

To [Lower] Greensand, in which water was got at the depth of 815 feet, there being apparently a hollow, the tubes going freely 18 feet below where the tools had been.

This section, which is barely 1½ miles westward of the dockyard-borings, agrees well with them as to the thickness of the beds; for although there is here less Chalk, it must be remembered that the site is not at the top of that formation, though near it.

Some of the tubes are said to have become magnetized, so that in lowering a bar it was pulled over to one side and held firmly; some of the boring-rods too were acted on in the same way.

* The Rev. O. Fisher says, in a letter to Prof. Judd, that Baily (*Ann. Nat. Hist.* July 1860) has wrongly referred this species to the Kimeridge Clay, whereas it was found by Mr. Fisher, in Oxford Clay, at Weymouth.

The only other instances of a like occurrence that I have heard of come from America. Mr. G. E. Broadhead has recorded that "in boring to the depth of 833 feet, the drill was often observed to be highly magnetized, but after that depth no further influence was observed" *; and in a "Report on the Artesian Wells of Denver," which forms the chief paper in the first volume published by the new local Society, Mr. F. F. Chisholm says, "Upon the subject of the so-called magnetic water, it is scarcely necessary to say that water cannot be magnetic. The magnetism observed is located in the casings, and is due to the magnetizing of the steel drill by friction and pounding, and this magnetism is communicated to the casing during the passage of the drill when lifted and lowered" †.

4. *Frindsbury. Chattenden Barracks, North of Upnor.* 1885.

Communicated by Col. R. Hawthorne, R.E. and Mr. H. G. Lyons, R.E.

127 feet above Ordnance Datum.

Shaft and cylinders about 200 feet, the rest bored.

Water from the three greenish sands (down to 123, 129 $\frac{3}{4}$, and 146 feet respectively) was ferruginous. Water rises to about 114 feet from the surface, and, after pumping two hours, at the rate of 5000 gallons an hour, could not be lowered below about 170 feet.

		Thickness in feet.	Depth in feet.
London Clay, 101 ft.	{ Brownish clay	16 $\frac{1}{2}$	16 $\frac{1}{2}$
	{ Blue clay	75 $\frac{1}{2}$	92
	{ Greenish sand and blue clay	9	101
Oldhaven Beds.	Gravel with chalk [? white flint pebbles] and shells	7 $\frac{1}{2}$	108 $\frac{1}{2}$
	{ Fine sharp sand, with water	6 $\frac{1}{2}$	115
	{ Green sand	3	118
	{ Greenish sand	5	123
	{ Shells closely packed in blue clay.....	5	128
	{ Hard black shale	1	129
Woolwich Beds, 59 $\frac{3}{4}$ ft.	{ Fine green sand.....	7 $\frac{3}{4}$	129 $\frac{3}{4}$
	{ Fine white sand	7	136 $\frac{3}{4}$
	{ Greenish sand, wet, and blowing from under cylinder	10	146 $\frac{3}{4}$
	{ Fine sand, almost on the move with water	20 $\frac{1}{2}$	167 $\frac{1}{4}$
	{ Blue clay, sand, and pebbles.....	1	168 $\frac{1}{4}$
Thanet Beds, 121 $\frac{3}{4}$ ft.	{ Green sand	16 $\frac{1}{4}$	184 $\frac{3}{4}$
	{ Blue sandy loam	105 $\frac{1}{2}$	290
Chalk		493	783
Gault (bluish-grey clay)		320	1103

In all likelihood there is some mistake in classifying so great a thickness of beds as Gault. It is not unusual for the clayey lower part of the Chalk to be so classed; and, as we have no reason to expect any thinning of the Chalk, but on the contrary may count

* Trans. Ac. Sci. St. Louis, vol. iii. p. 221.

† Proc. Colorado Sci. Soc. vol. i. p. 86 (1885).

on its continuing northwards with about the same thickness as at Chatham, it would be safer to take only about 130 feet of the boring as in Gault. In this case some 60 feet more should reach the bottom of that formation, and the progress of this boring (which is unfinished) may be of interest in showing us whether the Lower Greensand thins out altogether, as one might expect from its small thickness at Chatham.

The great thickness of the Thanet Beds here is notable, 121 feet being a good deal more than one would have expected.

Mr. Lyons has noticed, in a letter to me, that the section of the Tertiary Beds is almost identical with that of the neighbouring Upton pits*, and has classified the beds accordingly.

I have had, for some years, an account of a shaft at Chattenden Barracks, which seems to be a different version of the top part of this well, and may perhaps as well be noticed here. It was taken from a drawing (dated 1876) communicated by the Inspector General of Fortifications, and is as follows:—

		Thickness in feet.	Depth in feet.
[London Clay, 102 ft.]	{ Brown clay	17	17
	{ Blue clay	85	102
[Oldhaven Beds, 10 ft.]	{ Light-coloured silver-sand	5	107
	{ Shells, sand, and stones [? pebbles]	5	112
	{ Sand	8	120
[Woolwich Beds.]	{ Shells, dark earth, and stones	2	122
	{ Sand and shells	10	132
	{ Green sand.....	1	133

5. Boxley Grange, South of Chatham. 1885.

Bored and communicated by Mr. R. D. Batchelor, of Chatham, and from information and specimens from Messrs. Dunlop and Co.

		Thickness in feet.	Depth in feet.
	{ Old well		348
Chalk.....	{ Hard chalk, with flint, and alter- nate layers of soft chalk, with- out water	258	606
Chalk Marl, and Gault (a fine blue clay, hard and dry) ...		310	916
	{ Dead green sand	2	918
[Gault.]..	{ Light-brown clay	3	921
	{ Darker clay, specimen grey; also some crystals of pyrites at 922 ft.	4	925
	{ Dead green sand	1	926
	{ Dead green sand with pyrites ...	2	928
[Lower Greensand, or, in part, base of Gault.]	{ Dead green sand	4	932
	{ Rock	$\frac{1}{2}$	$932\frac{1}{2}$
	{ Dead green sand	$5\frac{3}{4}$	$938\frac{1}{4}$
	{ Rock	$\frac{1}{4}$	$938\frac{1}{2}$
	{ Waterworn light-coloured sand...	$4\frac{1}{2}$	943

In this case there is thickness enough for the Chalk, especially as the well does not begin in the topmost beds. A more detailed

* Geol. Survey Memoirs, vol. iv. pp. 144, 145 (1872).

account of the Chalk, as found in a well near by, may be seen in the Memoir on the London Basin*.

The amount of Gault seems to be in excess of that in the borings at and near Chatham.

6. *Chartham, South of Canterbury. Kent Asylum. 1874.*

From a tracing communicated by Mr. J. Giles.

254 feet above the level of the Stour.

Shaft 261 feet, with two headings of 100 feet in length, at 257 feet, the rest bored.

First water-level 231 feet down. Present water-level (? October, 1874) 238 feet down.

	Thickness in feet.	Depth in feet.
	261	261
	51	312
	8	320
	53	373
	11	384
	16	400
	60	460
Chalk, nearly 734 feet.	44	504
	230	734
	$5\frac{3}{4}$	740

Although this section, which has been in my hands for some years, does not show the whole thickness of the Chalk in East Kent (not beginning at the top of the formation), yet it marks the position of the base.

7. *Dover. Convict Prison, East Cliff. 1885.*

Made and communicated by Mr. R. D. Batchelor. Also from information and specimens from the Home Office.

180 feet above the level of the sea.

Shaft 315 feet, with headings at the bottom; the rest bored.

Water found at 315 feet, in headings, to the extent of 18,000 gallons a day.

* Geol. Survey Memoirs, vol. iv. pp. 463, 464 (1872).

	Thickness in feet.	Depth in feet.	
Surface soil	1	1	
[Chalk, 674 feet.]	Upper Chalk, with flints	249	250
	Middle Chalk, few flints	145	395
	Rocky yellow chalk, no flints	39	434
	Chalk Marl [=clayey chalk]	14	448
	Lower or grey Chalk.....	182	630
	Upper Gault or Chalk Marl [clearly the latter]	42	672
Gault	Upper Greensand [=green base of Chalk Marl], without water.....	3	675
		138	813
[Lower Greensand, 49 feet?]	Rocky dead green sand	1	814
	Dead green sand	2	816
	Hard boulder-rock.....	2	818
	Dead green sand. Specimen at 831 feet, fine greenish-grey clayey sand	31	849
	Black sand and clay	13	862
[Beds of doubtful age, 54 feet.]	Brown clay. Specimens at 875 feet, brown and brownish-grey clay; at 879 feet, brownish-grey and grey clay, mixed with chalky matter [? carried down the bore]	17	879
	Dark sand and clay	1½	880½
	Rock	½	881
	Light-brown clay, with a greenish tinge (and with a small quantity of sand?) ...	8	889
	Greenish clay (? and dark clay, with pyrites?).....	15	904
	White pipe-clay.....	10	914
	Greenish clay.....	2	916

It should be noted that of four accounts of this section that have been received only two agree in the description of the beds from the base of the Chalk downwards, and that the description giving most detail, and at the same time the clearest explanation, has been adopted.

Perhaps the Gault should have been carried 5 feet lower, on the inference that the 2 feet of rock may be the nodule-bed at the base of that formation, though it may be a sandstone, like that which occurs in the Folkestone Beds at the outcrop to the south. Perhaps, too, the Lower Greensand may have been carried 13 feet too low.

What formation the clayey beds at the bottom belong to is uncertain, no fossils having yet been found, though the workmen have somewhat cleverly tried to make up for this want by making impressions, from a small specimen of a recent *Nassa*, in the clay. Their earlier attempts, in the clayey greensand, are less artistic, fair-sized specimens of the shell of the aforesaid *Nassa* having been bodily included. It is possible, of course, that these clays may belong to the Wealden Series, but the one clean specimen that I have as yet seen seems to me more suggestive of a Jurassic origin. The occurrence of Kimeridge Clay would be interesting. Specimens are now under examination by Mr. Sharman.

It may be useful to reproduce here an account of a trial-boring,

perhaps not known to many of our Members, and at a site well fitted for further experiment.

St. Margaret's, near Dover. Trial-boring for the Channel Tunnel Company [on the shore]. Prestwich, *Proc. Inst. Civ. Eng.* [1874.]

	Thickness in feet.	Depth in feet.	
Shingle	9	9	
Upper or White Chalk, 240 feet.	White chalk	209	218
	Yellow chalk	4	222
	White chalk	4	226
	Fissure (salt water)	3	229
	White chalk	20	249
	Grey chalk	30	279
	White chalk	10	289
	Blue marl	11	300
	Pipe clay	42	342
	Light-blue clay	158	500
	Light stone	1 $\frac{3}{4}$	501 $\frac{3}{4}$
	Light clay	1 $\frac{1}{2}$	503 $\frac{1}{2}$
	Stone	1 $\frac{1}{2}$	504 $\frac{1}{2}$
Lower or Grey Chalk, 299 feet.	Clay*	2 $\frac{1}{2}$	507
	Stone	1 $\frac{1}{2}$	508 $\frac{1}{2}$
	Clay*	3	511 $\frac{1}{2}$
	Stone	1 $\frac{3}{4}$	513 $\frac{1}{4}$
	Clay*	10	523 $\frac{1}{4}$
	Stone	1 $\frac{1}{2}$	524 $\frac{1}{2}$
	Clay*	10	534 $\frac{1}{2}$
	Stone	$\frac{1}{2}$	535
	Clay*	10	545
	Greensand [=base of the Chalk Marl] ...	3	548
Gault Clay	19	567	

C. GEOLOGICAL RESULTS OF THE BORINGS.

Having the details of the two Chatham borings before us, together with those of the neighbouring Cement Works bore, we may now pass in review the various formations pierced, and see what information has been given by the work. Until the Chattenden boring has had further examination, I fear that it cannot help us much, except in so far that it gives the full thickness of the beds between the London Clay and the Chalk, a matter with which we have now no particular concern.

In the first place, with regard to the beds above the Chalk at the Dockyard, we learn but little; this, however, is of no moment, as the excavations for the neighbouring basins gave very fine sections of the alluvial beds; and it may be of interest to note that one of these sections yielded what may fairly be described as the largest fossil in the world—to wit, a Dutch Man of War, one of the fleet that sailed up the Medway in the time of Charles the Second, was sunk, and then buried by the river-deposits. The occurrence, however, of a few feet of loam between the gravel and the Chalk is of some importance; for if, as seems most probable, this represents

* "Clay" (in the Chalk) is probably used in the sense of marl, or marly chalk. One is hardly disposed to accept the above classification of Upper and Lower Chalk, but inclined rather to end the former higher up.

the base of the Thanet Beds, it shows that the whole of the Chalk is present.

The Chalk therefore being passed through from top to bottom, we have, for the first time, a measurement of its total thickness in the district. This is from 682 to 689 feet, according to the various accounts, a less amount than one might have expected, but which is confirmed by the section of the neighbouring boring at Frindsbury (Cement-works), showing 618 feet of Chalk at a point some way below where the Thanet Beds come in. The higher of the above figures (689) exceeds only by 18 feet the thickness of the Chalk in the Richmond boring*, and by 44 feet that in the Kentish Town section, which gives the least thickness of all the borings in the London Basin that pierce the Chalk from top to bottom†. In marking the probable position of the base of the Chalk in Sheets 78 and 84 of the so-called Horizontal Sections of the Geological Survey, which cross the Chalk and Tertiary district just eastward of Chatham, and in which that line was kept low for safety, I have erred by about 180 feet, having estimated the thickness of the Chalk as possibly reaching to about 870 feet.

The absence of the Upper Greensand is no more than we should expect; for there is none of this formation at the base of the Chalk hills to the south, although a narrow strip has been coloured on the Geological Survey Map (an error corrected in the Drift Edition now being engraved). The 18 inches of greenish-grey marly sand described by me as Upper Greensand (in the Memoir on the Weald, p. 153) is, of course, far too thin to be mappable; and, moreover, I should now class it as the base-bed of the Chalk Marl, the same as the Cambridge nodule-bed‡.

With regard to the Gault there is a difference of 6 inches in the two Chatham borings, and the Frindsbury well agrees remarkably with them, being but a foot less; so that the figures 192 and 193 may fairly be taken as the thickness of this bed here, where the slight dip would have but a trifling effect in exaggerating it. This tends to show that, as has been the case further west, too small a thickness may have been assigned to the Gault at the outcrop, which has been given as low as 100 feet, and that the supposed abnormal thickness at Trottescliffe, where the Gault was not bottomed after 183 feet had been passed through, is not so exceptional as has been thought§. Here, again, there is a fair agreement with the Richmond

* Prof. Judd, *Quart. Journ. Geol. Soc.* vol. xl. p. 724 (1884).

† 'Guide to the Geology of London,' ed. 4, pp. 20, 21 (1884).

‡ In Ed. 4 of the 'Guide to the Geology of London,' p. 16, first paragraph, the statement with regard to the deep wells of the London basin, that "in each case the Upper Greensand and the Gault succeeded in due order," should have been "in most cases the Upper Greensand and in all the Gault . . ." The mistake is a case of survival from a former edition, in which the statement was correct.

§ 'The Geology of the Weald,' *Mem. Geol. Survey*, p. 148 (1875). For the thicknesses of the various divisions of the Lower Greensand and of the Wealden beds at their outcrop I am indebted to this work. I have also to thank the author, Mr. Topley, for the trouble he has taken in getting together information on the Chatham borings.

section, which gives a thickness of only $9\frac{1}{2}$ feet more than the lowest of the above figures (192).

So far, therefore, nothing occurs to cause any surprise; but when we reach the Lower Greensand we are faced by new facts, though at first these are not particularly startling, as in sands one expects some irregularity. At the same time one would not have expected that the Folkestone Beds (the sands that form the uppermost division of the Lower Greensand) would have thinned away to 30 feet from the 100 feet at their outcrop to the south, the nearest point of which is less than seven miles off. No surprise would have been felt, however, if the more clayey Sandgate Beds, always thin and often inconstant, had been absent (as they are practically over the outcrop of the Lower Greensand to the S.W.); but they seem to be well represented by 11 feet of sandy clay, a thickness that compares fairly with that at the outcrop on the south.

After this, however, every previously known formation of the county of Kent is absent, and we are confronted by the total disappearance underground of beds that are well developed at their outcrop near by to the south, where, indeed, some of them occur in their greatest force.

Taking the absentees in downward order, we have firstly the Hythe Beds, with a thickness of 70 or 80 feet near Maidstone, the head quarters of the Kentish Rag (the most characteristic state of this division of the Lower Greensand). Their nearest point to the boring is but just over 7 miles, and they are thicker to the west.

Then of the thin clay that has been classed as Atherfield Clay, and which is some 15 feet thick in the Maidstone district, there is no trace.

The next formation wanting is the Weald Clay, the nearest outcrop of which is at the inlier at Maidstone, some nine miles away, where too it has proved to be 600 feet thick, in a boring. In the light of our new facts, however, one may perhaps question whether this 600 feet is really all Weald Clay, although that thickness seems not too great for the main outcrop a few miles to the south. The record is an old one, and probably specimens do not now exist; so we must be content to leave this question, and to accept the old reading.

Having now got rid of some 700 feet of beds, which crop out at no great distance from Chatham, we are prepared to lose the rest of the Wealden beds, which occur further off; and, indeed, one would be surprised if, in the absence of the lower part of the Lower Greensand and of the Weald Clay, any members of the Hastings Beds were represented. These increase our deficiency as follows:—The Tunbridge-Wells Sand by about 160 feet, the Wadhurst Clay by about the same, and the Ashdown Beds, the base of which is rarely seen in the Weald (and then in Sussex), by probably at least 400 more.

To continue, we have no trace of the Purbeck Beds, which, near Battle, underlie the last, with a thickness of over 300 feet; so that more than 1000 feet is added to the 700 above mentioned, and to this respectable total of over 1700 feet, nearly as much can be

added from the result of the Subwealden Boring, shortly to be referred to.

D. GENERAL REMARKS ON THE DEEP-SEATED GEOLOGY OF THE LONDON BASIN.

The facts of the Chatham borings being now before us, it may be profitable to compare them with those of the other deep borings in the London Basin, and to see whether the evidence of this sort now in the hands of geologists warrants any general conclusions as to the deep-seated stratigraphy of that large district. Firstly, let us take those borings along the Valley of the Thames, westward of Chatham, and then, having seen what occurs along this E. and W. line, examine the evidence to the north and to the south, in all cases beginning below the Gault, down to which point there is regularity.

The furthest boring westward of Chatham is that at Richmond, which has lately been described to the Society by Prof. Judd*, and is about 37 miles distant. Here we find 10 feet of beds which are probably Neocomian, whilst the Lower Greensand at its outcrop, fifteen miles or more to the south, is about 400 feet thick. To this succeeds 87 feet of Jurassic limestone, with clay, but of Great Oolite age; so that the whole of the Wealden Beds are here absent, as at Chatham, and also the Upper and Middle Jurassic (in the latter of which the Chatham boring ends). The Lower Jurassic beds are succeeded by what seems to be Trias, in which the boring ends at a depth of 1447 feet, the greatest reached in the London Basin.

Nine miles north-eastward we come to Meux's Brewery, where there is no trace of Lower Greensand, but only 64 feet of Jurassic limestone &c. (of the same age as that at Richmond) between the Gault and the Devonian shale, in which the boring ends.

In the Kentish-Town boring, about 3 miles to the north, the Gault is succeeded by a set of beds that may be Trias, though some geologists take them to be Old Red; and, as at Richmond, these possibly Triassic beds were not bottomed.

Over 11 miles further east from Meux's, at Crossness, a like thing occurs, the Gault being underlain by red beds, perhaps of Triassic age.

With regard to the argument against the red beds at Richmond being classed as Trias, from the fact that "nowhere else did an unconformity so marked occur between Oolitic and Trias," brought forward by Prof. Hughes in the discussion on Prof. Judd's paper †, one may remark that it applies only to the Richmond section, where the red beds are overlain by a Jurassic deposit. It does not apply to the cases of Kentish Town and Crossness, where the Gault comes next to the red beds. As, in the West of England, Cretaceous beds, overlapping the whole of the Jurassic Series (including the Lias),

* Quart. Journ. Geol. Soc. vol. xl. p. 724, vol. xli. p. 523.

† Quart. Journ. Geol. Soc. vol. xl. p. 763.

often rest at once on Trias, so a like thing may occur in the London Basin; and, even if the bottom-rock at Richmond should turn out to be Old Red, it does not follow that the same age must be assigned to the beds beneath the Gault in the other borings. Old Red moreover is not the only alternative in the Richmond case, Carboniferous rocks being often stained red.

From this to Chatham (over 19 miles E.S.E.) we have no deep boring passing through the Chalk; but the whole of this evidence shows that the ridge, or one should say rather the plain, of Primary rocks under the Thames Valley was under water long before Cretaceous times, being capped, though sometimes very thinly, by older Secondary beds, varying in age from Oxford Clay perhaps to Trias, but Lias not yet having been found, nor any member of the Upper Jurassic.

From London northwards we have (besides the Kentish-Town section) two deep borings:—firstly that at Cheshunt (Turnford)* about 13 miles northward of Kentish Town, in which the Gault is at once succeeded by Devonian shale, and then that at Ware (Broad Mead) † about $6\frac{1}{2}$ miles further north, where Upper Silurian beds occur at a higher level than any of the other old rocks in our other deep borings, and are separated from the Gault by only $1\frac{1}{2}$ feet of Lower Greensand. However, as we have no description of this thin bed, I am somewhat inclined to regard it rather as the base of the Gault.

Northward from Crossness the Loughton well (of which a description will shortly be published by the Essex Field Club) gives little information, having been carried only to the base of the Gault; and the older Saffron-Walden well gives none, the Chalk Marl, the Gault, and underlying beds having been lumped together, in the accounts that have been preserved, as Chalk Marl, with the impossible thickness of over 720 feet ‡.

From Chatham north-eastward we reach Harwich, at a distance of 48 miles; and here alone have we met with any marked irregularity in the Gault, which formation is but 61 feet thick, and is underlain by Lower Carboniferous rock. Further north the Combs boring (Stowmarket) § and the Norwich well || have not bottomed the Gault, and so give us no information as to the older beds.

I would remark, by way of caution, that, from the proved occurrence of Jurassic clays in some of our borings, the classification of a clay as Gault may be hardly safe, where uncorroborated either by fossil-evidence, as I believe is the case at Ware and at Harwich, or by the occurrence of underlying Neocomian beds. We have every reason to expect the constancy of the Gault; but we should not let this hinder us from seeing the possibility, small though it be, of the absence of that formation.

* See Trans. Herts Nat. Hist. Soc. vol. iii. pt. v. p. 176 (1885).

† *Ibid.* p. 179.

‡ See W. H. Penning in the 'Geological Survey Memoir,' on Sheet 47, p. 79 (1878). Also Proc. Norwich Geol. Soc. pt. 1, p. 28 (1878).

§ 'Geological Survey Memoir,' on Sheet 50 S.W. pp. 19, 20 (1881).

|| Proc. Norwich Geol. Soc. pt. 8, pp. 250, 251 (1884).

So far all our evidence as to what underlies the Cretaceous beds has been northward from the Valley of the Thames; and, indeed, we have but one piece of evidence (besides that of the Chatham boring) in the other direction, some way beyond the London Basin and 32 miles south of the Chatham site. This is from the Subwealden Exploration-boring, the deepest by far in the south of England, which, beginning in the Purbeck Beds, passed through a great thickness of beds that are wholly unrepresented, not only in the Chatham well, but also in all the others that have been referred to. These beds show a regular continuous series through 180 feet of Purbeck Beds, 60 of Portlandian, no less than 1120 of Kimeridge Clay, and of Corallian &c. 480 feet, to Oxford Clay; thus adding 1660 feet to the 1700 or more already shown to be wanting at Chatham, not counting the Purbeck Beds, some 350 feet thick in that neighbourhood, which have been already allowed for. In 32 miles we have therefore a loss of 3400 feet of beds, or a thinning at the rate of rather more than 100 feet in a mile.

It will be seen that this result bears out the leading idea of Mr. Topley's paper, "On the Correspondence between some Areas of Apparent Upheaval and the Thickening of Subjacent Beds"*, in which it is said that "perhaps the most striking and most important example of apparent upheaval being partly due to thickening of strata, is that afforded by the Weald." Probably, however, the underground thinning now recorded is much more than was reckoned on; though Mr. Topley went a long way towards the truth in one of the sections on his Model of the Weald†.

I may here remark that the late Mr. S. V. Wood, Jun., refused to contribute to the fund for carrying on the Subwealden boring, on the ground that he did not care to spend his money in sinking a very deep hole in clays, which process he inferred would be the result of the undertaking, and rightly, as the work was stopped at a depth of 1905 feet, when 65 feet deep in Oxford Clay.

As regards the general bearing of the facts that have been described, I think that it is simply in the line pointed out in 1880 and repeated last year‡, and it may be put thus, in a few words:—Whilst north of the Thames older rocks, as a rule, rise up beneath the Cretaceous beds, on the south newer rocks come in between the two, until, at our furthest point in that direction, these intermediate formations have alone been found, to the greatest depth reached.

There is little need to remind Fellows of this Society that the subject has but lately been brought before them in detail by Prof. Judd§. It is, however, so important, that one need not hesitate to go over part of the same ground again, independently.

As to the question of finding Coal Measures along the Valley of the Thames, it seems to me that a hopeful answer is possible, or at

* Quart. Journ. Geol. Soc. vol. xxx. p. 186 (1874).

† W. Topley and J. B. Jordan, Geological Model of the South-east of England and part of France, including the Weald and the Bas Boulonnais (1873).

‡ 'Guide to the Geology of London,' ed. 2, pp. 20, 21, ed. 4, pp. 22-24.

§ Quart. Journ. Geol. Soc. vol. xl. p. 724, and vol. xli. p. 523 (1884, 1885).

least that a negative one cannot be given; for we know not what may be hidden under the Jurassic and possibly Triassic beds that have been found; and Upper Silurian, Devonian, and Lower Carboniferous rocks having already been found, it would be strange if the Upper Carboniferous had been wholly swept off.

In reference to water-supply from the Lower Greensand, the dream of many a geologist and engineer, surely there is evidence enough to show that it is not worth any great expenditure, except perhaps on the south of the Thames Valley and not far from the outcrop. This perhaps may be made more plain by the following tabular statement of the beds found, below the Gault, in the eight deep borings that have been referred to, the only ones in the London Basin that give us this information. The numbers 1-4 refer to sites along an E. and W. line (roughly), whilst the letters A-D refer to those along the lines northward therefrom:—

Lower Greensand (Neocomian).

- 1. Richmond. Very thin.
 - 4. Chatham. Thin.
 - C. Ware. Trace (doubtful).
- The Loughton boring *may* also touch this formation.

Middle Jurassic.

- 4. Chatham. Not bottomed.

Lower Jurassic.

- 1. Richmond. Only 10 feet below the Gault.
- 2. Meux's. Next below the Gault.

Trias?

- 1. Richmond.
- 3. Crossness. Next below the Gault.
- A. Kentish Town. Next below the Gault.

Carboniferous.

- D. Harwich. Next below the Gault.

Devonian.

- 2. Meux's.
- B. Cheshunt. Next below the Gault.

Upper Silurian.

- C. Ware. Practically next below the Gault.

From this it follows that (so far as our slender data go) Jurassic beds or Trias are as likely to occur either next to or not far below the Gault as is Lower Greensand, there being three records of each, allowing Loughton to make up for the doubt at Ware. Moreover, the Lower Greensand, where it has occurred, is but thin. The balance of probabilities is therefore against the occurrence of Lower Greensand in the inner parts of the London Basin, and our evidence is decidedly against its presence in fair thickness. This formation may, of course, occur in many places, and in some it may be thick; but even then there is great chance of its being in patches, disconnected with the outcrop, or with but a slight connection. If it anywhere overlaps permeable Jurassic or Triassic beds there may be a water-

passage between the two, and the rain that falls on the Lower Greensand at its outcrop may pass into the Trias at great depths; but I doubt whether this possibility adds much to the chances of getting water from deep-seated beds.

It is to be hoped that the time is not far distant when further underground exploration may set at rest the important question of the possibility of getting coal in the South-east of England, and that such explorations may be carried out on a systematic plan carefully thought out beforehand, instead of being left to the chance efforts of corporations and companies, whose only object is to get water, in which, as a rule, less ambitious work would be more likely to lead to success.

It may not be out of place to draw attention to the three points of view from which an extended set of experimental deep borings may be approached (as I suggested to the late Mr. Godwin-Austen, when a Kentish boring was thought of some years ago).

Firstly we have *topographical* considerations, nearness to tracts where older rocks are known to occur; and in this respect Dover is well placed, at no very great distance from the outcrop of the Carboniferous rocks of Northern France.

Then we have the question of level, it being clearly of importance to begin such work at as low a level as possible: here, again, Dover is a good site, the lower part of the town being little above the level of the sea.

Lastly, there is the purely *geological* point, the beginning low down in the series of formations; and in this too Dover is fairly well placed, being a long way down from the top of the Chalk. The progress therefore of a deep boring at Dover should be watched with much interest.

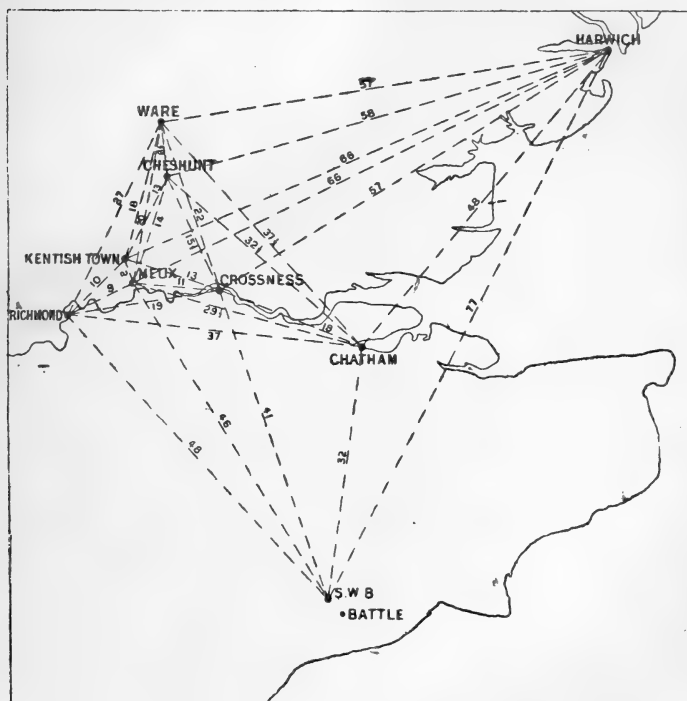
It is not meant, of course, that any one of these points should lead us, apart from others: indeed the failure of the Subwealden boring (as far as regards bottoming Secondary rocks) is a warning against too restricted a view, the site of that trial being admirably selected geologically: topographically the selection was unfortunately limited by a county-boundary. The experiments that I should like to see made should be cramped by no such arbitrary notion: they should not be parochial, but national, an application of our science to the good of our country.

E. EXPLANATION OF THE MAP AND SECTION.

The map (p. 45) is reduced from the Ordnance Index Map, which is on the scale of 10 miles to an inch. On it are shown, by dots, the sites of the Subwealden boring and of the eight borings in the London Basin which have passed through the Cretaceous beds to Jurassic or older rocks (not including the Saffron-Walden well with a depth of more than 1000 feet, of the bottom 720 of which no details have been kept). The relative positions and distances of these borings can therefore be seen at a glance. The sites have been connected by straight lines, along which are marked the distances, in miles, between each boring and every other,

except where that may be taken as the sum of two such distances, from these borings being almost in a straight line; and it is curious that in two cases these borings are in one straight line, so far as can be seen on a map of this small scale: these are firstly, Richmond, Meux's, and Harwich, and secondly Ware, Crossness and the Subwealden boring.

Sketch-Map, showing relative positions and distances of deep borings in the London district and South-east of England. (The numbers indicate distances in miles.)



It will be seen that the whole are enclosed in an irregular four-sided figure, of which the sides are 27, 48, 57, and 77 miles long. Of course the distances are not absolutely exact, but only as near as can be measured on such a map, and near enough for our purpose.

As it may be useful to have the distances between each boring and every other plainly before us, that information is given below in a tabular form, from which it follows that the greatest distance apart at which Jurassic rocks have been found in these borings is 48 miles, whilst for possible Trias the figure is 19, and for Devonian 14.

Table showing the Distances, in miles, between the sites of the Borings.

	Chatham.	Cheshunt.	Crossness.	Harwich.	Kentish Town.	Meux's.	Richmond.	Sub-Wealden.	Ware.
Chatham .....	...	32 $\frac{1}{2}$	19	48	32	29 $\frac{1}{2}$	37	32	37 $\frac{1}{2}$
Cheshunt	32 $\frac{3}{8}$	...	15 $\frac{1}{2}$	58	13	14	22?	56	6 $\frac{3}{8}$
Crossness	19	15 $\frac{1}{2}$	...	57	13	11	19*	41	22
Harwich	48	58	57	...	66	66*	75	77	57
Kentish Town	32	13	13	66	...	3	10	49	18
Meux's	29 $\frac{1}{2}$	14	11	66*	3	...	9	46	20
Richmond	37	22?	19*	75	10	9	...	48	27
Sub-Wealden	32	56	41	77	49	46	48	...	63
Ware	37 $\frac{1}{2}$	6 $\frac{1}{2}$	22	57	18	20	27	63	...

The section is made from parts of sheets 78 and 84 of the "Horizontal Sections" of the Geological Survey, the former of which runs across the Weald near Goudhurst and Marden, and the Lower Greensand tract near Maidstone, to the Chalk above Boxley, the latter then continuing the course down the dip-slope of the Chalk, over the Medway, through the Tertiary tract of the Hundred of Hoo, and over the Thames, into Essex.

The inferred positions of the bases of the Chalk and of the Gault in those sections have been corrected, and the geology has been carried somewhat deeper in the northern part (sheet 84) and to a much greater depth in the southern (sheet 78), in which latter, indeed, it had not been taken below the line of the sea-level, except just by the junction with the other sheet.

The Subwealden boring is on an exposure of Purbeck Beds between 5 and 6 miles eastward of the one crossed at the southern end of the section. The Boxley-Grange well is only about half a mile east of the section, near the Chalk escarpment. The Chatham wells are in a part of the Medway marshes about two miles westward of where the section crosses them. The Chattenden well is on the Tertiary hill north of the Medway, about the same distance from the section and on the same side of it. All these therefore have been available in estimating the position of the beds underground.

Whilst the section is an attempt to show, in a general way, what happens underground in the tract it crosses, of course it cannot pretend to exactness, either as to the places where the various thinnings-out of formations take place, or as to the manner in which they occur. Such formations as the Corallian and the Purbeck, being of comparatively local character, have been ended off fairly soon, whilst the thick deposit of Kimeridge Clay may be presumed to reach further. Again, though the various formations have been drawn as thinning out in a gradual way, it is very likely that there

is more irregularity, and even that there may be abrupt disappearance in some cases : as, however, we don't know the exact sites of disappearances, it would clearly be hazardous to mark any such occurrence strongly.

Judging by the deep borings in and near London, and by the Harwich boring, one would expect that the Oxford Clay does not range to a great distance northward from Chatham ; and therefore, some miles in that direction, the section has been made to agree with what happens near London, where the Gault next overlies beds of various ages, but all older than Oxford Clay. These beds have been massed together.

EXPLANATION OF PLATE III.

The Plate has been made from the original section, which was of the scale of six inches to a mile, horizontally and vertically, by reduction to a sixth, or an inch to a mile, horizontally, and to a third vertically. The vertical scale, therefore, is 2640 feet to an inch, and being only exaggerated to double the horizontal scale, there is, practically, no distortion. The reduction has been made by Mr. J. G. Goodchild, of the Geological Survey.

The horizontal scale being the same as that of the general Ordnance Map, and the line of section being expressed on the Geological-Survey version of that Map, it will be easy for any one possessing the latter map, and not very difficult for possessors of the former only, to follow the course of the section. This course, and the data on which the underground range of the beds has been shown, to great depths, have been noticed above.

DISCUSSION.

Prof. PRESTWICH remarked on the great value of the communication. He agreed that there was little hope of finding water in the Lower Greensand at great distances from the outcrop of that formation. With respect to the finding of the Coal Measures, he thought that somewhere in the district between the Thames, near Chatham, and Harwich were the places where they might most probably be found. He pointed out how analogous the succession of strata between Boulogne and the Palæozoic rocks of the Boulonnais was to that between the Battle boring, Chatham, and Harwich.

Mr. ETHERIDGE said that the different borings were of very considerable interest, taken in connexion with the facts previously known.

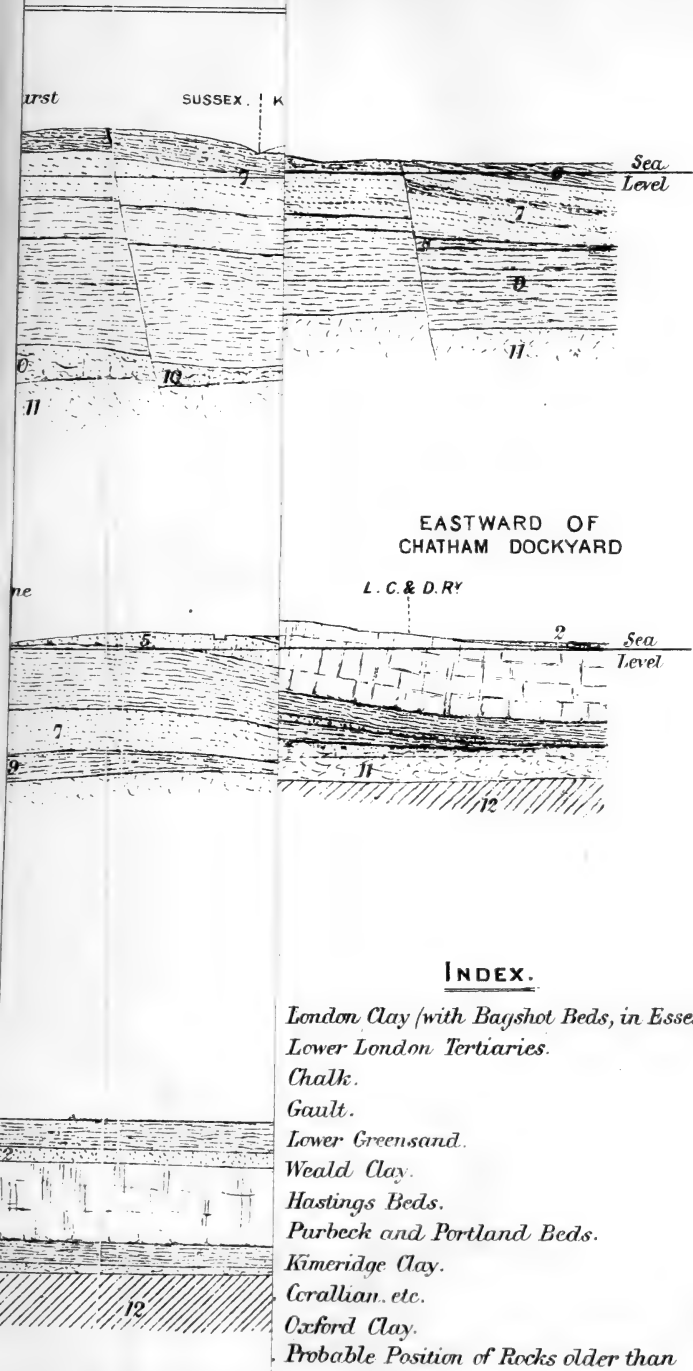
Mr. TOPLEY pointed out that the existence of the Oxford Clay beneath the South-east of England had been correctly inferred from the abundance of derived Oxfordian fossils in the Lower Greensand. He agreed with the author as to the previous under-estimate of the thickness of the Gault. He thought the borings lent some support to the view that the upper part of the Folkestone Beds belongs to the Gault rather than to the Neocomian.

Mr. EASTON did not think the Lower Greensand afforded a sufficient gathering-ground for water-supply. He doubted if the Coal

Measures would be found in the South-east of England, or whether it would be of any advantage if they were found.

Mr. CRESWICK felt some doubt whether the Upper Greensand was not present as a very thin bed, only 1 ft. 6 in. thick, in the Chatham well. He thought that the Oxford Clay might be a little thicker than shown in the section. An ample supply of water was obtained from the small bore first put down; but the second and larger boring was a complete failure; for the supply of 115,000 gallons per day was not increased in the well. The temperature of the water at Chatham showed a rise of 1° Fahr. for every $57\frac{1}{2}$ feet of descent, after allowing for the mean annual temperature. The water overflowed in a stand-pipe at the height of 19 ft. from the surface.

The AUTHOR said that Mr. Dalton had just told him of the magnetization of the boring-tubes at the Scarle boring. The bottom bed of the Chalk often contains green sand, so as to have been classed as Upper Greensand.



EASTWARD OF
 CHATHAM DOCKYARD

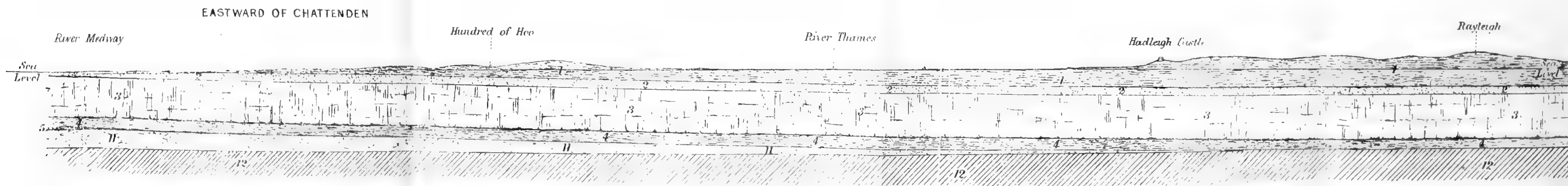
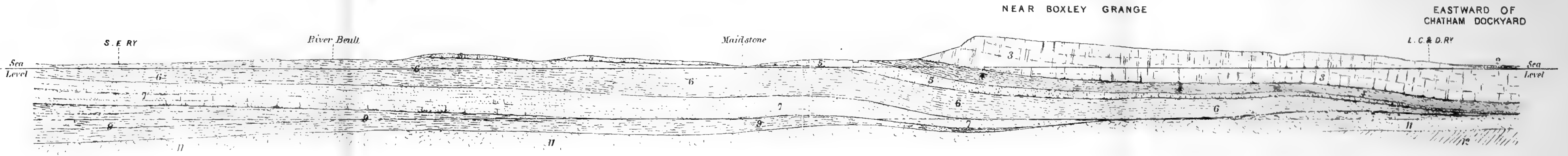
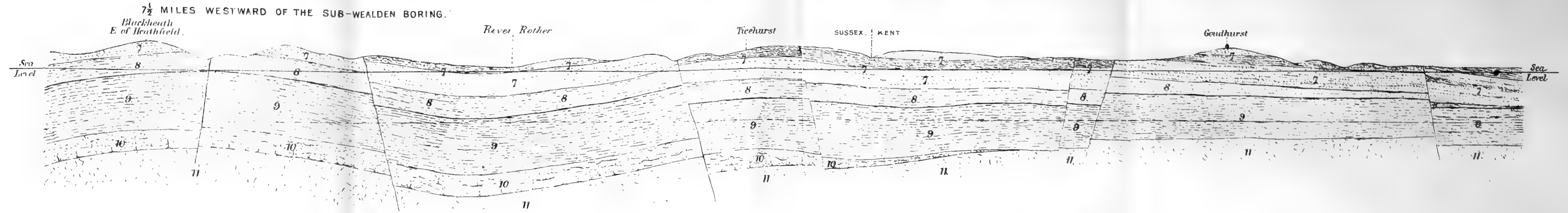
INDEX.

- London Clay (with Bagshot Beds, in Essex.)*
- Lower London Tertiaries.*
- Chalk.*
- Gault.*
- Lower Greensand.*
- Weald Clay.*
- Hastings Beds.*
- Parbeck and Portland Beds.*
- Kimeridge Clay.*
- Crallian, etc.*
- Oxford Clay.*
- Probable Position of Rocks older than
 Oxford Clay.*

a mile. Vertical Scale Line



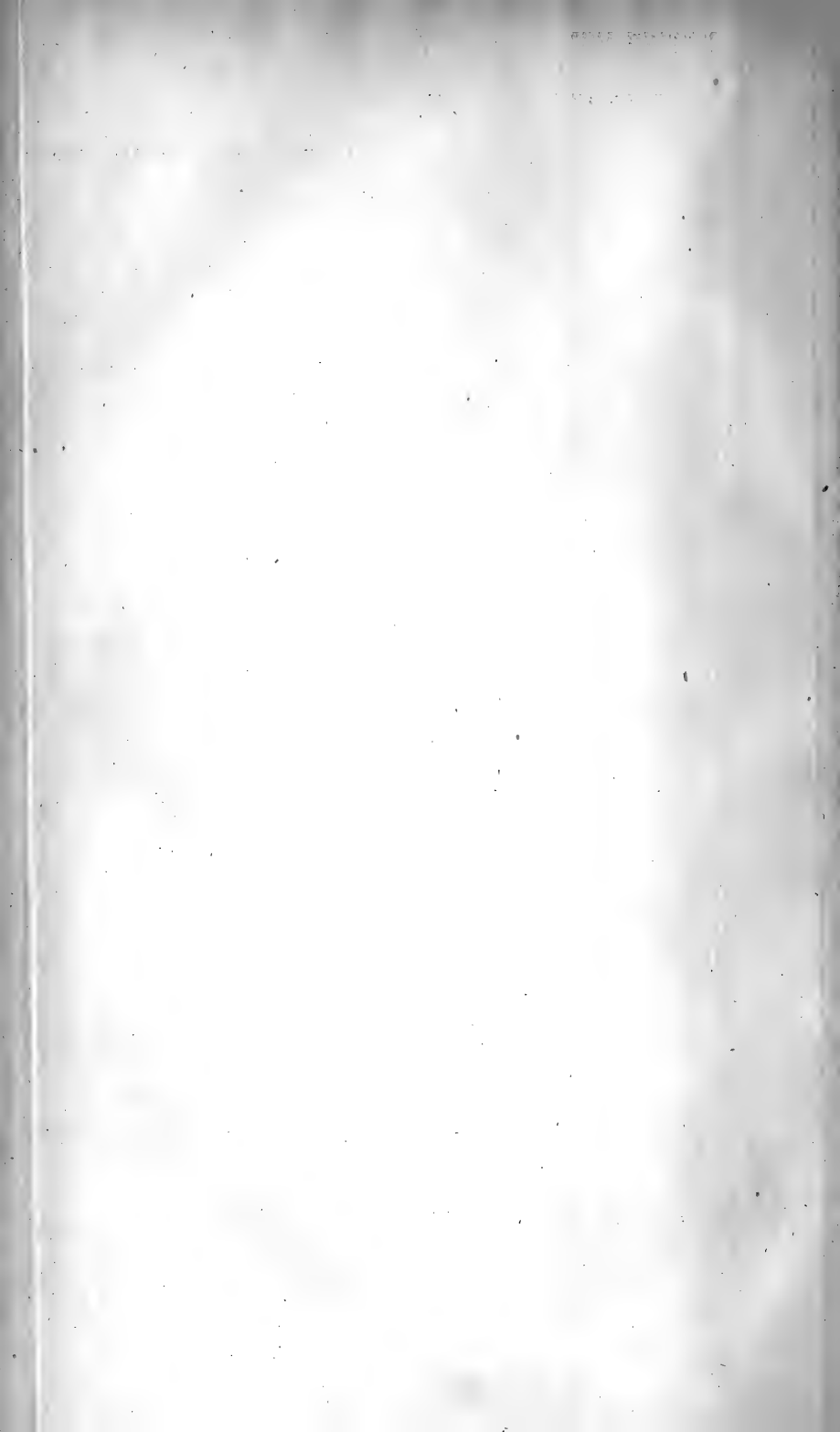
SECTION ACROSS THE WEALD OF SUSSEX AND KENT, AND ACROSS THE LONDON BASIN IN KENT AND ESSEX,
FROM BLACKHEATH, EAST OF HEATHFIELD TO RAYLEIGH, - GENERAL DIRECTION ABOUT S.S.E. TO N.N.E.



INDEX.

1. London Clay (with Bagshot Beds, in Essex.)
2. Lower London Tertiaries.
3. Chalk.
4. Gault.
5. Lower Greensand.
6. Weald Clay.
7. Hastings Beds.
8. Purbeck and Portland Beds.
9. Kimmeridge Clay.
10. Corallian, etc.
11. Oxford Clay.
12. Probable Position of Rocks older than Oxford Clay.

Horizontal Scale 1 inch to a mile. Vertical Scale 1 inch = 1760 feet.



6. *On the GABBROS, DOLERITES, and BASALTS, of TERTIARY AGE, in SCOTLAND and IRELAND.* By PROFESSOR JOHN W. JUDD, F.R.S., Sec. G.S. (Read December 16, 1885.)

[PLATES IV.-VII.]

- I. Introduction.
- II. Geographical Distribution.
- III. Geological Age.
- IV. Nomenclature of the Rocks.
- V. Minerals of which the Rocks are composed.
- VI. Proportions of the several Minerals in the Rocks.
- VII. Structures of the Rocks.
- VIII. Geological Relations of the Rocks exhibiting the several Structures.
- IX. Origin of the Structures.
- X. Principles which have governed the Crystallization of the Rocks.
- XI. Alterations which the Rocks have undergone.
 - § 1. Action of surrounding Magma upon Crystals.
 - § 2. Action of Solvents under Pressure (Schillerization).
 - § 3. Action of Steam and other Gases at the Surface.
 - § 4. Action of Atmospheric Agents (Weathering).
 - § 5. Effects of Crushing Movements in Rock-masses.
- XII. Summary of Results.

I. INTRODUCTION.

AMONG igneous rocks of every variety of chemical composition, the most highly crystalline types appear to have been formed in those cases only where the liquid magmas have cooled down with extreme slowness and under enormous pressure. Such conditions of slow cooling and great pressure it would seem must have existed when the rock has consolidated at great depths within the earth's crust; and hence it follows that the highly crystalline rocks now seen at the surface have been exposed through the removal, by denudation, of the vast deposits which originally overlay them.

Bearing these principles in mind, it is not difficult to find an explanation of the undoubted fact that the igneous rocks of Tertiary and recent date, *as a general rule*, exhibit far less perfectly crystalline characters than those which belong to the older geological periods. *Cæteris paribus*, the older a deep-seated igneous rock is, the greater will be the chance of its being exposed at the surface, through the removal by denudation of the mass of materials under which it was originally formed.

Further than this, it must be remembered, as Allport and others have so well shown, that the older a rock-mass, the greater is the probability that its constituent minerals will have undergone alteration, from the action of those chemical forces which are everywhere at work within the earth's crust. In this way the aspect, the structure, and even the mineralogical constitution of a rock may be so completely changed that its real relations with the unaltered type may easily escape recognition.

Now as the result of the more common occurrence of the crystalline

types among them, and of the changes which their constituent minerals have so frequently undergone, the older igneous rocks often, *but by no means uniformly*, present well-marked and sometimes very striking differences from those of younger date. These are the facts which have given rise to the opinion, now so widely accepted upon the continent, that there is a *fundamental* distinction between the characters of the rocks erupted during the Tertiary periods and those of rocks formed during earlier epochs of the earth's history.

That the differences which are usually relied upon for the distinction between the Tertiary and older igneous rock-masses are of the accidental kind to which I have been alluding, I think there cannot be the smallest doubt. But, on the other hand, there are strong *a priori* grounds for the inference that certain petrographic types may be characteristic of particular geological periods; and there are not wanting positive observations in support of the same conclusion. The refusal to recognize the real analogies which undoubtedly exist between the older and younger igneous rocks has not been an assistance, but rather a hindrance, to the study of comparative and stratigraphical petrography. The palæontologist does not invalidate the teachings of the stratigraphical geologist by admitting that *Ceratodus*, originally found in the Trias, is still a living genus; and the petrographer would do wisely to follow the biologist in basing his nomenclature and classification on purely morphological characters, without reference to the distribution of the objects of his study in space or time. If a palæontologist were to discover a fossil in Tertiary strata, presenting all the characters which he accepts as distinctive of *Ammonites*, he would unhesitatingly refer it to that group; but many petrographers, when shown a Tertiary rock presenting all the characters which are admitted to be distinctive of a gabbro, steadfastly refuse to call it by that name.

In the year 1874 I was able to demonstrate by a careful study of the district of the Western Isles of Scotland, that rocks which had been shown by so eminent a petrographer as Professor Zirkel to be very typical "olivine-gabbros," are really of Tertiary age, and that they graduate into less perfectly crystalline rocks, to which the name of dolerites may be conveniently applied; these dolerites, in turn, passing insensibly into basalts, which, where suddenly cooled, assume the form of tachylyte or basalt-glass. A study of the acid rocks of the same region showed that an equally insensible gradation could be found from granite, through quartz-felsite and rhyolite, into obsidian*. It was therefore insisted upon that the differences between gabbro and tachylyte on the one hand, and between granite and obsidian on the other, are not to be accounted for by a difference of geological age, but are a consequence of the diverse conditions under which the rocks had consolidated.

* Quart. Journ. Geol. Soc. vol. xxx. (1874), pp. 220-303. In employing the names "felsite" and "felstone" in this paper, I followed an old English usage of terms. As the rocks in question are, in all their fundamental characters, identical with quartz-felsite ("quartz-porphyr") and rhyolite, it would, I think, be wiser in the future to employ those terms for them. These rocks, as I shall hereafter show, are associated with others of less pronounced acid type.

Two years later, a study of the district of Schemnitz, in Hungary, enabled me to prove that what is true of the more basic and acid types of rock, respectively, is equally true of the rocks which have an *intermediate* composition ("roches neutres" of the French geologists). I showed that in Hungary, rocks which were commonly spoken of as "syenites" and "granites"—but which really belong to the diorites and quartz-diorites—are not only of Tertiary age, but graduate insensibly through the so-called "prophyrites" and "greenstone-trachytes" into the andesites and quartz-andesites, which sometimes assume a perfectly vitreous condition*.

These conclusions concerning the acid, the intermediate, and the basic classes of rocks, respectively, were arrived at mainly by the study of the rocks in the field; but the observations were confirmed, controlled, and checked at every point by the examination of transparent sections of the rocks with the microscope.

Although these conclusions have met with a very general acceptance among my fellow-workers in this country, it would be idle to conceal from myself the fact that they have found but little favour among the petrographers of Europe †. In spite of the support which the views I have advocated have received from Professor Süss ‡ and Dr. Reyer §, of Vienna, and from Dr. H. H. Reusch ||, of Christiania, the absolute distinction in age between the highly plutonic and the volcanic types of igneous rocks has been maintained and strongly insisted upon in nearly all the valuable petrographical treatises and monographs which have appeared in Germany and France since the date of the publication of those papers. Such being the case, I have felt it to be my duty to carefully review

* Quart. Journ. Geol. Soc. vol. xxxii. (1876), pp. 292–324. See also 'Volcanoes: what they are and what they teach' (1880), pp. 198–200.

† In the year 1876, Professor Zirkel met my contention with respect to the propylites or "greenstone-trachytes" of the older authors, by endeavouring to show that constant and recognizable differences existed between those rocks when compared with the diorites on the one hand, and the andesites on the other (U. S. Geol. Expl. of 40th Parallel, vol. vi. pp. 111, 112). These views were to some extent also supported by Professor Vom Rath. But, on the other hand, Dölter, in 1879 (Verhandl. der k. k. Reichsanstalt, 1879, p. 27), felt compelled to admit that rocks certainly occur in which the supposed distinction failed to apply; and Szabó has also argued against propylite being regarded as a distinct rock-species (Verhandl. der k. k. Reichsanstalt, 1879, p. 18 &c.). The same view was maintained with respect to the American "prophyrites" by Dr. Wadsworth in 1879 (Bull. Mus. Comp. Zool. Camb. Mass. vol. v. p. 285) and 1881 (Proc. Bost. Soc. Nat. Hist. vol. xxi. p. 2), and with regard to the Hungarian ones by Dr. Koch, of Klausenburg, in 1880 (Verhandl. der k. k. Reichsanstalt, 1880). Most of the geologists of the United States Geological Survey, had followed Richthofen and Zirkel in regarding propylite as a distinct rock-species, which was erupted at a definite geological period; but in 1882 Mr. G. F. Becker was able to announce the results which he had arrived at by long and careful study in the field and in the laboratory. His conclusion was that the rocks in question have no real claim to be ranked as a distinct rock-species, but are really members of the diorite-andesite series (U. S. Geol. Survey, Monograph III., Geology of the Comstock Lode).

‡ Antlitz der Erde (1883), pp. 204–206.

§ Beitrag zur Physik der Eruptionen und der Eruptivgesteine (1877) p. 135 &c.

|| H. H. Reusch, 'Ueber Vulkanismus' (Berlin, 1883).

the evidence upon which I relied in arriving at my former conclusions, with the aid of those important methods which in recent years have been introduced into petrographical research through the labours of crystallographers and chemists.

Although the present memoir has been somewhat delayed in its appearance by the necessity for considering and weighing the vast amount of evidence which has been adduced upon the other side of the question, by authorities whose position demanded the most careful consideration of their views, yet I venture to hope that the delay has enabled me to treat the question with greater thoroughness than would have been possible if I had written at an earlier date. The present paper forms a sequel to that which I published last year on the intimately associated peridotites of the same district.

The views which I enunciated in 1874 and 1876 have recently met with the strongest support from the observations recorded by Messrs. Arnold Hague and J. P. Iddings, of the U. S. Geological Survey. In their very remarkable monograph "On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, with Notes on the Geology of the District"* , they state that a careful microscopic study of the extensive series of rocks collected by the survey during the mapping of the district around the celebrated Comstock Lode, has led them to the conclusion that the most highly crystalline rocks of the district are—like the associated andesite and other lavas—of Tertiary age; and they further show that highly crystalline varieties, like quartz-porphry, quartz-diorite, diorite, and diabase, graduate respectively into rhyolite, dacite, andesite, and basalt. The great interest of this investigation, and that which constitutes its chief novelty, arises from the fact that the specimens upon which the conclusions are based were obtained from *artificial* excavations—the great Sutro Tunnel and deep shafts made for mining-purposes around the Comstock Lode—while my own observations were made on specimens derived from rock-masses laid bare by the natural agents of denudation.

In no class of igneous rocks does the apparent distinction between the older and younger types come out more strikingly than in those of *basic* composition. This is due to the circumstance that the minerals of which these rocks are composed are, as a rule, less stable, and therefore more liable to be converted into pseudomorphs, than the minerals of either the acid or the intermediate class of rocks. In the case of these basic rocks it is of especial importance to distinguish between the original minerals and those which are secondary. Now the Scottish representatives of the basic class of igneous rocks are of especial interest to the petrologist on two distinct grounds. In the first place we are able, as I have shown, to determine from their present positions the approximate depth from the surface, and the other conditions under which the several varieties must have consolidated; and, secondly, although they do not present us with examples of all the *extreme* results of alteration in the minerals of which they are composed, they exhibit the *incipient* stages of most of these

* Bulletin of the U. S. Geological Survey, No. 17 (1885).

changes; and from such we may often learn more of the nature and mode of operation of the processes by which the changes were brought about, than from a study of the final products of the alteration. I have already discussed in my paper on the closely associated peridotites* of the district, the nature and causes of some of the mineral metamorphoses to which I refer; and the present paper is to a great extent a continuation of that already published.

II. GEOGRAPHICAL DISTRIBUTION.

The rocks which I now propose to describe in detail cover considerable tracts in the Inner Hebrides and the adjoining mainland of Scotland, extending to the southward over the north-eastern part of Ireland. Rocks with identical characters again make their appearance, however, to the northward, in the Faroe Isles, and in Iceland—in the last-mentioned island covering very large areas.

The admirable descriptions of the Icelandic basic rocks which have been given by many geologists, among whom may be mentioned Krug von Nidda, Sartorius von Waltershausen, Professor Zirkel, and especially M. R. Bréon †, enable us to show the remarkable similarity in characters which exists between the basalts of Iceland and the Faroe Isles on the one hand, and those of Scotland and Ireland on the other. Nor are the more highly crystalline forms, approximating in character to our dolerites and gabbros, altogether wanting in Iceland, though they are as yet imperfectly known. Such highly crystalline rocks occur in ejected blocks, and also forming isolated peaks, as at Baula. The occurrence of these peaks of crystalline basic rocks has been interpreted as necessarily implying the existence of a series of pre-Tertiary igneous rocks, around which the later volcanic masses have accumulated; but the examples in the British Isles may well suggest a doubt as to the correctness of this explanation of their mode of occurrence. The tracing-out of the relations of the different igneous rock-masses in Iceland is rendered difficult, not only by the existence of permanent snow-fields and by the inaccessibility of large portions of the island, but also by the covering of volcanic products resulting from recent eruptions. There has not been, as in the British Isles, a long cessation of accumulation which would permit of the uncovering of the deep-seated plutonic masses by denudation. My comparison of the British and Icelandic types of rock has been greatly facilitated by the gifts of a number of Icelandic specimens from friends who have travelled in different parts of that island; among these I have especially to mention my obligations to Professor John Milne, Mr. W. Watts, and Mr. J. Starkie Gardner.

The more carefully we study the British and Icelandic types of Tertiary basic rocks, the more forcibly are we struck with their essential identity in character. Not only do certain peculiarities, to be hereafter noticed, again and again recur in the rocks of both areas, but if we compare them with rocks of the same age and of

* *Quart. Journ. Geol. Soc.* vol. xli. (1885) pp. 354-418.

† *Notes pour servir à l'étude de la Géologie de l'Islande et des Iles Fœroë* par R. Bréon (Paris, 1884).

similar composition in other districts, such as the Auvergne, Bohemia, or Italy, we shall find that there are groups of characters in the rocks of each of these areas which are highly distinctive.

These facts point to two important conclusions. The first is that there are distinct *petrographical provinces*, within which the rocks erupted during any particular geological period present certain well-marked peculiarities in mineralogical composition and microscopical structure, serving at once to distinguish them from the rocks belonging to the same general group, which were simultaneously erupted in other petrographical provinces. The second conclusion is that Antrim, the Inner Hebrides, the Faroe Isles, and Iceland were, during the Tertiary period, included in the same petrographical province*.

This petrographical province was one of vast extent. From Iceland, which covers an area of nearly 40,000 square miles, the Faroe Isles lie 250 miles to the south-east; while the St. Kilda group, an extreme outlier of the British Archipelago, lies another 250 miles still further to the south. Although I have not been able to visit the last-mentioned remote group of islands myself, the clear descriptions of Dr. Macculloch leave no doubt as to the remarkable identity in the character of its rocks with those of Skye, Ardnamurchan, and Mull. Mr. Alexander Ross, of Inverness, who has visited the islands, rendered me the greatest service by kindly supplying me with an interesting series of photographs and specimens. The former show that the characteristic modes of weathering of the acid and basic rocks so admirably exhibited in the Inner Hebrides are there exactly repeated; and the latter enable me to prove that the gabbros, dolerites, basalts, quartz-diorites, and granites of St. Kilda present precisely the same features as are found in the corresponding rocks of Mull and the other volcanic centres.

More than 100 miles to the south-east of the St. Kilda group, we find another, and perhaps the largest, centre of eruption in the district, the portions of the mass of erupted matter which have escaped destruction by denudation, forming the greater part of Skye, Raasay, and the adjoining islands. The Shiant Isles constitute perhaps only an outlying member of this group.

South of this centre of eruption, at a distance of less than 20 miles, is a third, the materials thrown out from which constitute the group known as the Small Isles (Rum, Canna, Eigg, and Muck).

* I have elsewhere pointed out ('Volcanoes: what they are and what they teach' (1880), p. 202) the family likeness which is found to exist between the different classes of lava erupted within a certain area during a given geological period, and their marked distinctness from those of other areas or other periods. Nowhere do we find this more admirably exemplified than in Bohemia and Hungary, where volcanic outbursts were taking place during a great part of the Tertiary period. While in the former district phonolites and tephrites, with nepheline- and leucite-basalts, were being erupted, in the latter none of these lavas made their appearance, their place being taken by andesites and quartz-andesites, rhyolites and felspar-basalts. In precisely the same way the several varieties of the igneous rocks of the Brito-Icelandic petrographical province are seen to exhibit the most striking resemblances to one another, while they show very well-marked differences from those of other areas.

Twenty miles east-south-east is a fourth centre of eruption lying in the peninsula of Ardnamurchan. Still further in the same direction, at the distance of another 20 miles, is the fifth centre, from which the volcanic masses of Mull and Morvern with the adjoining islands were erupted.

Now in the midst of each of these five areas we find, as I have already shown, representatives of the most highly crystalline basic rocks (gabbros), which are seen, when traced towards the peripheral portions of the area, graduating insensibly into dolerites, basalts, and finally into basalt-glass or tachylyte. What is more, the masses of gabbro and dolerite are found to be intrusive in other masses of more acid types of rock—granite, quartz-diorite, and diorite—which are also seen to graduate into the volcanic types known as rhyolites, dacites, and andesites. The whole of these more acid rocks, though older than the basic series, are still of post-Cretaceous age.

Those who would insist that the highly crystalline rocks—granites, diorites, and gabbros—are necessarily of pre-Tertiary age, and that the appearances presented in the Western Isles of Scotland may be accounted for by supposing Tertiary lavas to have accumulated above and around older highly crystalline rock-masses, are confronted by the startling fact that at no less than *five distinct and perfectly isolated* centres, we have the same remarkable collocation of crystalline rocks with lavas of identical composition. But as a matter of fact, as I have already shown, the transition of the most highly crystalline types of the several rocks into less crystalline, thence into true lavas, and finally into vitreous types, is alike manifested whether we study the rocks in the field or in the laboratory.

There is reason for believing that in Arran, 70 miles east-south-east of Mull, we have another centre of Tertiary eruption for rocks mostly of acid types. Fifty miles south-west of Arran we find the great basaltic plateaux of the north-east of Ireland. This is the largest of these areas of Tertiary volcanic rocks, except that of Iceland; but the structure of the igneous masses is not so admirably exposed by denudation as is the case with the Scottish examples. The fine coast-sections, it is true, exhibit many intrusive masses, like those of Portrush and Fair Head, which I have carefully studied; while other highly crystalline rocks are said to be exposed more or less clearly in the interior of the district.

Southward of the great basaltic plateaux of Antrim, however, we find in the Carlingford district another great centre of eruption both for the acid and basic rocks of this period. Here denudation has exposed the deep-seated masses in the same manner as in the Western Isles of Scotland, and the correspondence of the rocks of the two areas in all their essential characters is most striking.

Although no igneous masses which are certainly of Tertiary age are found further to the south than the Carlingford district, yet a great plexus of dykes, more or less distinctly connected with those great centres of eruption, can be traced all over the West of Scotland and the northern parts of England and Ireland.

The great band of Tertiary eruptive rocks which we are consi-

dering is thus seen to extend, from north to south, over a distance of 700 miles, or ten degrees of latitude.

III. GEOLOGICAL AGE.

There is one question which lies at the very foundation of my arguments on this subject, that, namely, of the true geological age of the rocks, and this question must therefore be dealt with at the outset. Is it established beyond all possible doubt that the rocks were really erupted in Tertiary times? As there still appear to prevail unfortunate misconceptions on this point, and some continental geologists have given extensive currency to the opposite view, it may be necessary to recapitulate, as briefly as possible, the evidence upon the subject—evidence which I hold to be absolutely conclusive.

Dr. Macculloch, in 1819, clearly showed that the basalts of the Western Isles of Scotland are most intimately associated with the rocks we now designate as “gabbros”; he characterized the whole of these “trap rocks” as an *overlying* formation, which was proved to be of later date than all the Secondary strata of the district, not only by the fact that it rests on these latter, but by its sending off numerous apophyses which penetrate and alter them. He went further than this and insisted, as the result of his studies, that the period of the eruption of the whole of the igneous masses was separated from that of the deposition of the Secondary strata by a great interval*. Murchison subsequently showed that the Secondary strata referred to by Macculloch include various members of the Lias and Oolite; he even thought that he had detected representatives of the Wealden, but these have since been shown to be of Oxfordian age†.

In 1851, Professor Edward Forbes announced that the plant-remains of Ardtun which had been found by the Duke of Argyll in deposits interbedded with the basalts of Mull, are of Tertiary age‡. Shortly afterwards, he was able to correct Murchison’s identification of certain beds in Trotternish, in Skye, with the Wealden§; but in doing so, he suggested the possible contemporaneity of the basaltic rocks of that area with the Jurassic deposits so intimately associated with them, illustrating these views by a diagrammatic section. It must be remembered, however, that Edward Forbes, as he himself tells us, had no opportunity of studying the relations of these rocks beyond that afforded by a short yachting cruise, and that he expressly cautions his readers against accepting his conclusion as being anything more than a suggestion. He writes as follows:—

“Another view may be taken, however, of the origin of the basaltic sheet intervening between the Upper and Middle Oolites in Skye, one which would seriously affect the preceding estimate of its

* Western Isles of Scotland (1819), vol. ii. p. 67, &c.

† Trans. Geol. Soc. 2nd ser. vol. ii. p. 292, and *ibid.* p. 353.

‡ Quart. Journ. Geol. Soc., vol. vii. (1851), p. 103.

§ *Ibid.* pp. 104–117.

date. It may be regarded as intruded trap, insinuated between superior and inferior strata at an epoch long posterior to that of the deposition of the former. A minuter investigation of the geological phenomena of the north and west of Skye than has yet been made will probably determine which view is the right one beyond question. But in the present state of the evidence, I incline to regard the basalt as contemporaneous with the Oolites, and as of the definite date which its position in sequence of beds seems to indicate”*.

In 1860, Dr. A. Geikie adopted the suggestion of Forbes with respect to the Jurassic age of a portion of the volcanic rocks of the West of Scotland †; but he also guarded himself, as Forbes had done before him, and admitted that there was doubt whether the igneous masses associated with the Oolites are not intrusive rather than interbedded.

But in 1867‡, Dr. A. Geikie fully withdrew this suggestion as to the Jurassic age of the Hebridean igneous rocks, so far as Mull and the adjoining islands were concerned, and in this and subsequent publications§, returned to the views which had always been maintained by Macculloch, namely, that the whole of the igneous masses are of later date than the Secondary strata, and that, wherever associated intimately with these latter, they constitute intrusive sheets and dykes. He also added some interesting observations in support of the view that these igneous rocks are of Tertiary age, the chief among them being that there exist river-gravels made up of chalk-flints interbedded with the basalts at Carsaig in Mull.

Now it is a most unfortunate circumstance that some continental geologists have adopted the suggestion of the late Professor E. Forbes, and of Dr. A. Geikie, without noticing their reservations; while they appear to have altogether overlooked the fact of the complete abandonment of the hypothesis of the Jurassic age of these igneous rocks by the latter author.

In 1871, Dr. Zirkel published his “Geological Sketches of the West Coast of Scotland,” in which he gives a section of Trotternish, in Skye, based on the erroneous one of Edward Forbes ||; he does not appear to have been acquainted with the earlier and correct views enunciated by Macculloch, nor of the acceptance of those views in the end by Dr. A. Geikie. This misleading section has unfortunately been copied into the different editions of Dr. Credner’s admirable and widely known ‘Elemente der Geologie,’ and its French translation.

During my own survey of the Secondary rocks of the west coast of Scotland, I was able to show that not only are Jurassic rocks represented in that area, but that we find important deposits

* *Loc. cit.* p. 109.

† *Trans. Roy. Soc. Edinb.* vol. xxii.; see also ‘Scenery and Geology of Scotland’ (1865).

‡ *Proc. Roy. Soc. Edinb.* vol. vi. pp. 71–75.

§ *Brit. Assoc. Rep.* 1867. Address to Geological Section, p. 52. *Quart. Journ. Geol. Soc.* vol. xxvii. (1871) pp. 279–310.

|| *Zeitschr. d. d. Geol. Gesell.* vol. xxiii. (1871), Taf. iv. f. 13.

of the age of the Upper Greensand and the Chalk. It was proved that these Cretaceous rocks, which include strata younger than the zone of *Belemnitella mucronata*, are overlain unconformably by the great sheets of basaltic rock*.

In the north of Ireland the proofs of the Tertiary age of these igneous rocks is equally clear and convincing. Everywhere they are seen overlying the eroded surfaces of the "white limestone" (Chalk), which includes beds certainly as high in the series as the zone of *Belemnitella mucronata*. They contain, moreover, interbedded deposits like those of Mull, which have yielded numerous remains of a Tertiary flora.

With respect to the exact portion of the Tertiary period to which the plants obtained from the strata intercalated with the basalts of Scotland and Ireland should be referred, some misconception seems to have existed; but we may confidently hope that the persevering researches which are now being undertaken by Mr. J. Starkie Gardner will throw much new light upon this interesting question.

It has been shown, by both Dr. A. Geikie and myself, that the great basaltic plateaux are broken through by intrusive masses of still later date†. I have found no evidence of any volcanic outbursts having taken place in the British area at anything approaching to recent times. In Iceland, however, where the general mass of the strata, judging from the plant-remains and other fossils contained in interbedded strata, must be of Tertiary age, the volcanic action has continued on a grand scale down to the present time, though there are not wanting evidences that this volcanic action may now be approaching the stage of final extinction.

The facts which I have now passed in review warrant the assertion that the igneous masses of this Brito-Icelandic petrographical province—from the most acid to the most basic in composition, and including representatives of every variety of structure, from the most highly crystalline to perfectly vitreous types—are all of post-Cretaceous age, and must have been erupted during different portions of the Tertiary epoch, coming in some cases quite down to recent times.

IV. NOMENCLATURE OF THE ROCKS.

There is fortunately no difference of opinion among petrographers as to the name which should be applied to the imperfectly crystallized types of the rocks we are considering; all authors are agreed that they should be referred to the "basalts." The great mass of the lava-streams that have built up the plateaux of Antrim and the Western Isles of Scotland belong to the felspar- or plagioclase-basalts; and, as I shall show in the sequel, to the same type of those rocks which is so largely represented in Iceland. As in Iceland, too, the successive outflows of basaltic lavas were occasionally

* Quart. Journ. Geol. Soc. vol. xxxiv. (1878) pp. 728-737.

† *Ibid.* vol. xxvii. (1871) p. 294; *ibid.* vol. xxx. (1874) pp. 260-267.

interrupted by the ejection of streams of augite-andesite lava of a peculiar type; but in both these districts such lavas are of comparatively rare and even exceptional occurrence. There is, in fact, a remarkable uniformity in the chemical composition of the basic rocks of the whole district, from Iceland in the north to Ireland in the south. But while some of the rocks are remarkably fresh and unaltered, others are converted into amygdaloidal varieties, some of which are undistinguishable from the so-called melaphyres, basaltites, and palatinites of the older geological periods. Nowhere do we find more striking evidence than in the Scóttish Isles that the degree of alteration in an igneous rock is not an infallible criterion of its geological age.

It may be interesting to recall the circumstance that certain rocks, once confounded with the basalts of this district, were for a long time adduced as affording the most striking evidence of the truth of the Wernerian doctrine of the origin of basalt by "aqueous precipitation." It is almost needless to remark that the so-called "basalt containing *Ammonites*" of Portrush, Co. Antrim, is nothing but a Lias shale altered by contact with the dolerites and basalts, which have been intruded into it. The temporary interest which was aroused with respect to these rocks, when the fossils were supposed to be actually imbedded in the basalts, has, of course, altogether subsided, now that the true relations of the igneous and aqueous masses are better understood.

In the Tertiary basalts of the British area, as in those of Iceland, we find every variety, from forms which are nearly holocrystalline and contain only a minute proportion of glassy residuum between the crystals, to others in which the great mass of the rock exists as a ground-mass or imperfectly crystallized base (magma-basalts). In both areas tachylytes or perfectly vitreous forms of the basalt are found, which are sometimes porphyritic, but they appear to be only rare and exceptional occurrences, which can in every case be accounted for by the abnormally rapid rate of the cooling of the rocks*.

But when we turn to the consideration of the holocrystalline types of these rocks, greater diversity of opinion as to their proper nomenclature is found to exist. As I have shown in my previous paper †, the misconception as to the true nature of the pyroxenic constituent of the rocks has led to much of the confusion; but in 1871 Professor Zirkel showed that the pyroxene in question is undoubtedly diallage, and that the rocks present all the characters which petrographers agree to be distinctive of the "olivine-gabbros." Professor Zirkel made a careful microscopical study of a series of specimens from Mull, and of another series from Skye. He showed that in both districts the rocks are made up of perfectly crystallized plagioclase felspar, diallage, and olivine, the whole of the minerals abounding with fluid-cavities. He further pointed out that the olivine of these rocks exhibits the characteristic structure of the olivine of gabbros, a structure which he had never found in that mineral as it occurs in basalts.

Professor Zirkel insisted, and rightly insisted, that as these rocks

* See Quart. Journ. Geol. Soc. vol. xxxix. (1883) pp. 444-465.

† *Ibid.* vol. xli. (1885) p. 357.

exhibit all the characters which petrographers have agreed to be distinctive of gabbros, they ought to be called by that name and no other*.

The determination of these rocks made by Professor Zirkel in 1871 was very strongly supported by the researches of Professor von Lasaulx in 1878 †. This author's observations were made upon a series of specimens from the Carlingford Mountains. He pointed out that these rocks have the closest analogy with the olivine-gabbros of Mull and Skye; that, like those rocks, they contain plagioclase felspar (anorthite or a variety approaching that species), diallage, and olivine, with some magnetite of secondary origin. Professor von Lasaulx also found that the minerals of the Carlingford rock contain both liquid and solid enclosures.

Both Professor Zirkel and Professor von Lasaulx are agreed that the characters of these rocks are those of true gabbros, and they insist on their exact similarity in mineralogical constitution and microscopic structure with typical gabbros, like those of Silesia, Norway, and Northern Italy. It is, I think, certain that, had not the Tertiary age of these rocks been demonstrated, no petrographer would have dreamed of removing them from the class of the gabbros.

In the year 1877 Professor Rosenbusch published his very valuable work, 'Mikroskopische Physiographie der massigen Gesteine,' in which he unfortunately assumed that fundamental distinctions exist between the igneous rocks which were erupted before the Tertiary period and those which have made their appearance since the commencement of that epoch. Referring to these and similar rocks, he writes:—"If we carry out consistently the nomenclature employed in this book, then Zirkel's designation of the Hebridean rocks as gabbros is incorrect. These rocks would bear the same relation to basalt as olivine-gabbro to olivine-diabase, and would therefore have to be characterized as diallage-basalts of granular structure" ‡.

The French geologists have, on the other hand, proposed to restrict the term gabbro to the older crystalline basic rocks, and for the similar rocks of more modern date to employ Haiiy's name "euphotide." But M. de Lapparent, in applying this name to the rocks of Skye and Mull as well as to those of Liguria, makes the express admission that "there are modern euphotides which are not distinguished in any way from the ancient gabbros" §.

The geologists and petrologists of this country have always refused to recognize the geological age of a rock as a character upon which its classificatory position and nomenclature ought to be based. They regard such a proceeding as both inexpedient and impracticable—inexpedient, inasmuch as it prejudices the question of the distribution of rocks in time; and impracticable, in that there are many eruptive rock-masses of which it is quite impossible to determine the geological age.

* Zeitschr. d. d. Geol. Gesell. xxiii. (1871) pp. 58 & 93.

† Tschermak's Min. und Petr. Mitth. vol. i. (1878) pp. 426-433.

‡ Loc. cit. p. 476.

§ Traité de Géologie, 2^{me} éd. (1885) p. 634.

It will be seen, then, that these Hebridean rocks have come to occupy a crucial position in the controversy which has arisen concerning the classification and nomenclature of igneous rock-masses. If they are truly gabbros, as maintained by Zirkel, Von Lasaulx, and the geologists of this country generally, then it must be admitted that the principle of the classification of rocks by their geological age, having been found inapplicable in this case, has received a severe, and, indeed, a fatal shock.

Those who advocate a purely *mineralogical* classification of rocks have always insisted that the characteristic mineral of gabbro is the diallage. But so long ago as 1862 it was shown by Streng that in many of the gabbros of the Harz we find the diallage replaced by ordinary augite *. In following Zirkel's classification of the Scottish rocks as gabbros, in 1874, I pointed out that the pyroxene was sometimes in the form of true augite and sometimes occurred as diallage †. The same mutual replacement of augite and diallage I have found to occur in all gabbros which I have examined, in which the alteration of the rock had not gone so far as to mask the true character of the pyroxenic constituent. In my paper on the peridotites it is shown that the diallage of the Scottish rock has in all cases been produced from ordinary augite by the process for which the name of "schillerization" is proposed.

By some authors the sole distinction which has been made between the gabbros and the diabases has been that the former contain diallage and the latter ordinary augite. Hence it may be argued that if the distinction between these two mineral varieties be given up as a basis of rock-classification, the name of diabase has as good a right to be adopted as that of gabbro. But against this contention I would point out that the use of the old Italian name of "gabbro" for the class of rocks in question was proposed by Von Buch as long ago as 1810 ‡; that from the first it seems to have been applied to highly crystalline rocks, as indicated by the synonyms "granitone" and "granito di gabbro;" and that its use in that sense is now almost universal, not only in this country, but in Germany, France, Italy, and North America. The term "diabase," on the other hand, though originally proposed by Alexander Brongniart, was only restricted to pyroxenic rocks by Hausmann in 1844 §; many authors too, down to quite recent times, have employed "diabase" as a name for rocks which are not perfectly holocrystalline, but contain a considerable proportion of unindividualized ground-mass. If, then, it becomes a question between the use of the terms gabbro and diabase for the highly crystalline representatives of the basic series of rocks, I think there cannot be the slightest doubt that the verdict should be given in favour of gabbro, both on the ground of priority and on that of the consistent use of the term by authors in the past.

* Neues Jahrb. für Min. &c. 1862, p. 943.

† Quart. Journ. Geol. Soc. vol. xxx. (1874) p. 237.

‡ Magaz. der Ges. naturf. Freunde zu Berlin, vol. iv. p. 128.

§ 'Ueber die Bildung des Harzgebirges.'

It has been usual among petrographers to divide the gabbros into two classes, the "olivine-gabbros" and the "olivine-free gabbros." But I have shown that in most cases where olivine is thought to be absent from these rocks, it has really been altered into magnetite or serpentine*. I believe that all the gabbros in their unaltered condition contained olivine, though in very varying proportions; and that in the few cases where we find a rock of this class in which olivine is not represented as an original constituent it should be classed with the eucrites. Such being the case, I do not think it desirable to perpetuate the name of "olivine-gabbros."

As I shall show in the sequel, the characters of the most highly crystalline of the Scottish and Irish basic rocks are exactly those of the rocks which have been universally classed by geologists as gabbros. Between these and the basalts, however, we find a number of other types which completely bridge over the interval between them. It would be a strain on the accepted definitions of these two classes of rocks to include all these rocks with intermediate types of structure either in the one or the other group. Consequently I have employed for them Haiüy's name of "dolerite."

In using this term I have to admit the impossibility of suggesting any precise definition of it. But this follows as a natural consequence—and constitutes, indeed, the strongest confirmation of the conclusion upon which I have always so strongly insisted—that when the microscopic textures of the rocks are carefully studied, the gabbros are found graduating insensibly into dolerites, the dolerites into basalts, and the basalts into tachylytes.

As a matter of convenience it may, perhaps, be desirable in practice to apply the term basalt to such rocks only as contain some remains of a vitreous base or ground-mass, and the term gabbro to those which present the most distinct "granitic" structure, the felspar crystallizing in broad plates, the spaces between which are filled by the crystalline substance of the pyroxene and the olivine.

Restricted in this way, the term dolerite would be given to those holocrystalline basic rocks in which the felspar appears in section as an entangled mass of lath-shaped crystals, while the augite and olivine occur either in definite crystals or rounded grains.

The gabbros never occur as lava-streams. Some of the very massive lava-currents of Scotland, Ireland, and Iceland, however, are true dolerites, according to the above definition; though most of the lavas contain more or less of a glassy base, and so fall into the class of basalts. The largest intrusive masses are gabbros, those of intermediate size dolerites, and the smallest ones basalts. In a large eruptive mass the central part may be a gabbro, passing into a dolerite in its peripheral portions; it may give off apophyses which have consolidated as basalt, and these latter have occasionally marginal selvages of tachylyte.

* Quart. Journ. Geol. Soc. vol. xli. (1885), p. 410.

V. MINERALS OF WHICH THE ROCKS ARE COMPOSED.

In a previous paper* I have pointed out that the ultra-basic rocks (dunites, picrites, eucrites, troctolites, lherzolites, &c.), which are so intimately associated with the gabbros and dolerites of the Western Isles of Scotland, are made up of the same minerals as the latter rocks, but grouped in different proportions. As I have already discussed the chemical composition and other peculiarities of these minerals in detail, it will not be necessary to do more than merely refer to the results which were there arrived at.

In making a study and comparison of crystalline rocks it is of the utmost importance, as I have already insisted, that we should discriminate between the minerals which belonged to the rock at its first formation and those which are of secondary origin. Many of the erroneous and contradictory statements which have been made by petrographers have resulted from a failure to recognize this fundamental distinction. At the same time, it must be admitted that the distinction is not always an easy one to arrive at; indeed in many cases doubts may remain after the most persevering study.

Among the original minerals, it is clear, when we come to study them with care, that certain crystals have separated out from the magma at a period quite different from that of the formation of other crystals. This fact has been very justly insisted upon by MM. Fouqué and Michel-Lévy, who have pointed out the necessity for discriminating between the several different periods of separation of the crystals in a rock. The solution of this important problem must, of course, be sought for in a study of the relations which the several kinds of crystals are seen to bear to one another when the rocks are examined in thin sections under the microscope. Further, if we study the positions of the several crystals of the different minerals which have separated during the same period of consolidation, we shall find certain facts, such as the inclusion of the crystals of one mineral in those of another species, or the assertion of the outward crystalline form of one mineral at the expense of others, which enable us to establish a distinct order of crystallization among them.

The *original* minerals of the rocks may be conveniently divided into two groups: those which are always present in every sample of the particular rock, which we may call the *essential* constituents; and those which occur with greater or less frequency in addition to the essential ones, which may be called *accessory* or *accidental* constituents.

The essential minerals of the most highly crystalline forms of these rocks (gabbros) are three only, plagioclase feldspar, augite, and olivine. As the rocks, however, become less perfectly crystalline, magnetite and a certain proportion of glassy ground-mass also take their place as essential ingredients in them.

The range in composition and characters of the essential minerals of these rocks has been already pointed out. Chemical and optical tests alike prove that the feldspars vary in composition between

* Quart. Journ. Geol. Soc. vol. xli. (1885), p. 362.

anorthite and labradorite*. When there have been two distinct periods of consolidation for the felspar-crystals, the oldest are always the most basic in composition and approach anorthite.

The augites seldom, if ever, exhibit evidence of having separated at two different periods. But in different varieties of the rock they present a wide range in chemical composition, from diopsides and chrome-diopsides to highly ferriferous augites, as is shown by the series of analyses given †.

The olivines exhibit the same wide range of variations in composition, from the iron olivines (fayalite) to the lime-iron olivines.

Seeing that the oxides of iron do not separate as magnetite in the most highly crystalline forms of these rocks, it follows that the olivines and pyroxenes of the gabbros should be more highly ferriferous than those of the dolerites and basalts. Observation fully confirms this inference, the most highly ferriferous varieties of augite, enstatite, and olivine being found in the more perfectly crystalline varieties (gabbros).

Some of the accessory minerals, such as apatite and garnet, must be regarded as additional constituents; others clearly replace to a certain extent one or other of the essential constituents.

The most striking case of this substitution of one mineral for another in these rocks, is the appearance of enstatite in the place of augite. The enstatite in every case plays exactly the same rôle in the rock as the augite. More than this, a highly ferriferous augite is usually replaced by a highly ferriferous enstatite, and a less ferriferous augite by a less ferriferous enstatite. Indeed the relations between those two minerals in the rocks we are considering seems

* To the series of analyses quoted in my former paper, I am able to add the following:—Mr. J. F. Brooks, at my request, isolated a sample of the felspar from a very typical specimen of the gabbro of Beinn More in Mull. This work was executed in the Geological Laboratory of the Normal School of Science and Royal School of Mines, by the removal of the heavy ferro-magnesian silicates from the powdered rock with the electro-magnet and by the use of Klein's borotungstate solution. A very satisfactory specimen of the felspar was obtained in this way, which, on analysis, gave the following result:—

Silica	47.90
Alumina	31.30
Iron oxides.....	Trace
Magnesia.....	1.16
Lime	11.22
Soda.....	3.96
Potash.....	.98
Loss on ignition	1.54
	<hr/>
	98.06

Mr. Brooks informs me that the deficiency in this analysis probably arises from a slight loss in the silica and magnesia; the titanitic acid was not separately estimated. It will be seen that the felspar is a labradorite. The percentage of magnesia is accounted for by the quantity of serpentinous matter which has penetrated into the cracks of the crystals, as is seen to be the case when thin sections are examined under the microscope.

† Quart. Journ. Geol. Soc. vol. xli. (1885), p. 368.

almost to point to the conclusion that the augite and enstatite in rocks may sometimes be dimorphous forms of the same substance*.

More or less ferriferous biotite occurs not unfrequently in these rocks, and seems also to take the place of the augite, though not in so striking a manner as enstatite.

In the same way the place of the magnetite is, in certain varieties, taken by the isomorphous chromite and picotite, and by the heteromorphous titanoferrite.

The secondary minerals in these rocks are exceedingly numerous, and their exact determination is often a very difficult problem.

I have already shown how, in deep-seated rocks, as a consequence of the schillerizing process, the felspars become filled out with secondary products, acquiring thereby aventurine and chatoyant characters, while the augites pass into diallage and pseudo-hypersthene, the enstatites into bronzite and hypersthene, and the olivines also acquire similar and distinctive characters.

By other processes of chemical change to be hereafter more distinctly specified, many new minerals crystallize out from the products of decomposition of these rocks; among the principal of these are quartz, uralite, hornblendes (with the actinolitic varieties known as smaragdite), biotites, "saussurite" (including zoisite), and other epidotes, kaolin, various zeolites, serpentine, hæmatite, with several hydrous varieties of ferric oxide, and leucoxene. In addition to these we must note a number of uncrystallized substances, to

* It is true that the large crystals which have generally been studied by mineralogists show the augites to be essentially lime-magnesia-iron silicates, and the enstatites essentially magnesia-iron silicates; but the series of analyses of microscopic rock-forming enstatites cited by Mr. C. Whitman Cross (U. S. Geol. Surv. Bull. I. 1883, p. 29) indicates the existence of a very considerable proportion of lime in some of them, while the series of analyses published by Merian (Neues Jahrb. für Min. iii. Beil. Bd. 1884, p. 252-316) appear to show that among the rock-forming augites there are not only some in which the proportion of magnesia is very high indeed, but that it sometimes actually exceeds that of the lime (see also Teall, Quart. Journ. Geol. Soc. vol. xl. (1884), pp. 648, 649). I need scarcely refer to the fact that Oebbeke and other mineralogists have asserted the existence of a monoclinic pyroxene which has the marked pleochroism of a ferriferous enstatite, and strongly simulates its characters. I have myself found in an example of the piperno of Pianura near Naples a crystal of augite which is beautifully zoned. The interior of this crystal has the cleavage and optical properties of a ferriferous augite, but the outer zone, which is not cut off by any sharp line of demarcation from the interior, exhibits the marked and peculiar pleochroism of a ferriferous enstatite. Both the inner and outer portions of the crystal appear to have the same extinction-angle. This outer zone is unfortunately too narrow to permit of the characters of its interference figures being determined by convergent polarized light. In the same way augite is sometimes found acquiring the peculiar pleochroism of hornblende before assuming its cleavage and other distinctive properties (see Plate VII. fig. 5).

It appears to me that all the known facts of the case point to the conclusion that mixtures of the bisilicates of lime, magnesia, iron, &c. are dimorphous and may crystallize in the rhombic system (enstatites) or in the monoclinic system (augites); but that the formation of enstatite, especially in *large* crystals (and of such mineralogists have until recent times alone taken cognizance), is favoured by an excess of magnesia over lime, and of augite by the excess of lime over magnesia.

which petrographers have been in the habit, perhaps not very wisely, of giving such names as "viridite," "opacite," and "ferrite," and which can sometimes be detected assuming crystalline forms, though the species of the minerals may be very difficult to define. Lastly, the amorphous glass may take up water and assume the characters of palagonite.

VI. PROPORTIONS OF THE SEVERAL MINERALS IN THE ROCKS.

Among the more highly crystalline types of these rocks, there is found the greatest diversity in the proportions of the several minerals which constitute them. I need not point out how greatly this will affect the bulk-analyses of such rocks; such analyses, indeed, must be almost useless in the case of very highly crystalline types, unless the analyst has selected in the field a specimen which appears to be of average mineral constitution, or has been able to "sample," by some means or other, a number of different specimens!

Professor Zirkel, from his examination of the Mull gabbros, was led to the conclusion that the three constituent minerals exist in the following proportions in these rocks:—plagioclase felspar 3, olivine 2, diallage 1*. A general examination of the rocks over the whole area leads me rather to conclude that while felspar is usually the predominant constituent, the pyroxenes are more abundant than the olivine. But within a very small area—and this is notably the case in Ardnamurchan and Rum—we may find examples of these rocks containing the most diverse proportions of the three constituent minerals. Some varieties from Ardnamurchan are made up to the extent of at least three fourths of their mass of felspar, while in others the felspar is the least abundant of the three constituents (see Plate IV. figs. 3 & 4).

This inequality in the relative proportions of the constituents is exhibited in an exaggerated manner in the "contemporaneous" veins and inclusions; these are often binary compounds of the essential minerals of the gabbros, or form varieties in which one or the other constituent is present in excessive proportion.

It has been already pointed out how, by the disappearance of felspar, the gabbro passes into picrite, by the disappearance of augite, into troctolite, and by the disappearance of olivine, into eucrite; while by the excessive development of accessory constituents like enstatite and picotite fresh varieties such as lherzolite may arise.

VII. STRUCTURES OF THE ROCKS.

It is not necessary to recapitulate the evidence that the gabbros, the dolerites, the basalts, and the tachylytes do not present any essential difference in their bulk-analysis †; that is to say, their chemical composition varies within the same comparatively narrow limits; and there is nothing therefore in their ultimate constitution to forbid the idea that all of these rocks may have consolidated from magmas containing the same chemical elements in identical proportions.

* Zeitschr. d. d. Geol. Ges. Bd. xxiii. (1871) p. 59.

† Quart. Journ. Geol. Soc. vol. xxx. (1874) pp. 233-236.

In their mineralogical constitution these rocks also present remarkable analogies; and these come out more strikingly if we make due allowance for the different kinds of alteration which minerals undergo when they exist in deep-seated igneous masses and in lavas poured out at the surface. All these rocks, except such as are perfectly vitreous in structure, contain plagioclase felspar, augite, and olivine. In the deeply-seated forms, the augite, as the result of secondary changes, is often found converted into diallage, and the olivine is more or less completely obscured by the development of secondary magnetite. In rocks which have consolidated nearer the surface, more or less magnetite has separated from the original magma, and a greater or less proportion of the latter has consolidated, without crystallization, into a vitreous ground-mass.

It is in their structure that we find the chief distinctions between the several groups of the basic rocks; and the main object of this memoir is to inquire whether there is anything in these structures, as studied by the aid of the microscope in the different varieties, which is opposed to the conclusions arrived at by observations in the field.

These field-observations point most distinctly to the conclusion that the degree of crystallization of an igneous rock affords no criterion as to its geological age, but is determined by the distance from the surface at which it has cooled down. In the district specially described by me it was shown that the most highly crystalline varieties of these rocks originally formed the centres of the largest volcanic cones, such as those of Skye, Ardnamurchan, Mull, and the Carlingford district. In the peripheral portions of these great mountain-masses, as well as in the centres of similar but smaller masses, and in sheets and large dykes proceeding from them, we find a less perfect crystallization of the materials. In the lava-streams and smaller dykes, clearly connected with the same centres of eruption, we find more and more of the materials remaining in the uncrystallized or vitreous condition; while in situations where very rapid cooling has evidently taken place, as on the sides of dykes, basalt-glass has been formed.

I shall now proceed to show, from the microscopic study of a very large series of specimens, collected in all parts of the district, that the study of these rocks in the laboratory fully bears out the conclusions arrived at in the field. In classifying the several rock-structures, I have been led to adopt a nomenclature almost identical with that proposed by MM. Fouqué and Michel-Lévy, and now very generally employed by French geologists. But I shall show that, distinct as these types may appear to be, they really pass into one another by the most insensible gradations. It will be my further aim to determine the causes by which the same magma cooling down under diverse conditions, is made to assume such remarkably different structures.

The chief structures which I have been able to define in the rocks under consideration are as follows:—

1. *The Granitic Structure* (see Plate IV.).—In the rocks exhibiting

this structure, the only minerals present (if we exclude those of secondary origin) are felspar, augite, and olivine. The growth of the crystals of these several minerals has taken place in such a way, that their full development has been interfered with by the consolidation of the neighbouring minerals. Nevertheless, the felspar seems to have had a distinct advantage in the order of its development over the other minerals. This is shown by the fact that when any crystal-faces are produced they are those of the felspars. Not only are the augite and olivine moulded on to the felspar-crystals, but in some cases the felspar-crystals may be found to have separated along cleavage-planes, and the augite-substance has penetrated into, and crystallized within, the spaces thus formed (see Plate VII. fig. 1). The felspar-crystals, in the most perfectly granitic types, appear in section as broad plates, sometimes exhibiting zonal structure, and not in narrow lath-shaped forms. The size of the crystalline grains varies greatly; in Ardnamurchan and Skye, the individual grains sometimes exceed an inch in diameter, but sometimes they are so fine as to be almost microscopic. These finer varieties have been distinguished as "*micro-granitic*" or "*euritic*."

2. *The Ophitic Structure* (see Plate V. fig. 1), which was first clearly defined by M. Michel-Lévy, is very admirably illustrated in our series of rocks. In the rocks of this type the crystals of felspar, which are lath-shaped in section, were evidently the first formed, for they are often found to be completely enclosed in large individuals of pyroxene and sometimes of olivine and magnetite. The enclosing pyroxene crystals sometimes attain considerable dimensions, but seldom, or never, have their outer faces well developed; in spite of the felspar-crystals enclosed in them, however, the persistence of cleavage-cracks and the mode of polarization shows the crystalline continuity of the whole individual. Where these crystalline individuals of pyroxene attain large dimensions, as in the rocks of Portrush and the Shiant Isles, the reflection from their broad cleavage-faces in fractured surfaces causes the rock to assume a striking and characteristic appearance. In Mull, certain lavas are found exhibiting this structure on a very minute scale, and these may be distinguished as *micro-ophitic* (see Plate V. fig. 5).

3. *The Granulitic Structure* (see Plate V. fig. 2).—In the rocks exhibiting this type of structure, we sometimes, but by no means always, find magnetite added to the other three original constituents of the rock. The most notable distinction in these rocks is found in the character of the pyroxene and olivine grains, which, as seen in section, assume more or less rounded outlines, and are imbedded in a plexus of lath-shaped crystals of felspar; in polarized light these grains are seen not to be parts of one large crystal, but to have very different orientations. The form of the individuals of pyroxene and olivine at once recalls the structure seen in the granulites. Although never so coarse-grained as some of the granitic forms, the granulitic varieties exhibit a wide divergence in the size of the individual minerals, and the finer varieties may be distinguished as *micro-granulitic* (see Plate V. fig. 6).

The structures which we have now described belong to the "holocrystalline" rocks of Professor Rosenbusch, the "type granitoïde" of M. Michel-Lévy. The hemiocrystalline rocks, rocks in which only a part of the magma has assumed the crystalline form before consolidation ("porphyrische Gesteine" in part of Rosenbusch, and "type trachytoïde" of Michel-Lévy), have now to be considered.

If to the granulitic or orphitic types of these rocks there be added a greater or smaller amount of vitreous ground-mass, we have the structure which characterizes the basalts. It may be convenient, with Möhl and Borický, to separate as a subgroup the varieties in which the quantity of vitreous or semivitreous base is excessive, under the name of "magma-basalts," these magma-basalts graduating insensibly on the one hand into ordinary basalts, and on the other into basalt-glass.

When we study with care the micro-structure of this more or less perfectly vitreous base—which forms the mass of basalt-glass, a large proportion of the magma-basalts and a smaller proportion of the ordinary basalts—we are struck with the fact that two strikingly distinct types of structure are recognizable among its numerous varieties.

In the first of these types we find the glassy ground-mass filled with opaque skeleton-crystals of magnetite and numerous long transparent rods often bifurcating at their ends; these appear to be skeleton-crystals of either augite or felspar, or of both those minerals. When the development of this structure has gone a little further it is often possible to identify the skeleton-crystals as those either of augite or of felspar. These opaque and transparent skeleton-crystals are seen entangled with one another in every position, and forming a crystalline network within the glass (see Plate VI. figs. 1, 3, 5, 7).

In the second type of vitreous base we find the opaque material in the form of cubical or more or less rounded grains, either isolated or irregularly aggregated. The felspar usually forms small and short microlites, the ends of which often exhibit step-like terminations, and the augite, when individualized, forms more or less rounded granules (see Plate VI. figs. 2, 4, 6, 8).

This distinction between the types of the glassy ground-mass in basalts can be made out alike in cases where the well-developed crystals are numerous, and in those in which they are comparatively few in number (magma-basalts). It is equally well seen, though developed on a more minute scale, in the basalt-glasses, some of which, as shown by Mr. Cole and myself, are filled with magnetite "dust," while others exhibit skeleton-crystals of magnetite and sometimes of transparent minerals*.

Porphyritic varieties are found in the case of all the different types of these rocks, from the most perfectly holocrystalline to those which are absolutely vitreous. While the rocks of this area are rendered "porphyritic" by the presence of scattered crystals of

* Quart. Journ. Geol. Soc. vol. xli. (1885) p. 444. plate xiv.

felspar, and sometimes of grains of olivine, we seldom, if ever, find porphyritic crystals of augite or of the hornblende-variety known as "basaltine." In this respect the rocks of this area differ in the most striking manner from the basic rocks of other petrographical provinces, such as that of Bohemia, for example. Another feature by which the basic rocks of the Brito-Icelandic province are distinguished is the absence of nodules composed of olivine and enstatite; such nodules are of the most common occurrence in Bohemia, the Eifel, and the Auvergne, but, so far as my own experience goes, they are wholly wanting in the district we are considering. The frequency with which the different varieties of the ophitic structure are exhibited is also another distinctive character of the basic rocks of this petrographical province.

Porphyritic Gabbros.—In Skye and Ardnamurchan, we find examples of gabbros in which crystals of felspar, sometimes from one to two inches in length, appear to have crystallized before the mass of crystals composing the groundwork of the rock. In some cases the earlier separation of these felspar-crystals is proved by the fact that they have cracked along certain planes of weakness, allowing the pyroxenic material to penetrate into them and crystallize there (see Plate VII. fig. 1). Such porphyritic gabbros appear to be exact analogues in the basic series of the porphyritic granites (like that of Shap, for example) in the acid series.

Porphyritic Dolerites.—The varieties of these are very numerous, and among them may be detected the exact analogues of rocks which have been designated "labradorit-porphyr," and "diabase-porphyr" in Germany, and also of those which have received the name of "labradorites" from the French geologists.

The porphyritic varieties of the granulitic dolerites contain, scattered through their midst, broad, platy, felspar individuals, like those characteristic of the gabbros; and these large felspar-crystals not unfrequently exhibit the zonal structure. In some cases the outlines of these porphyritic felspar-crystals are clear and well defined, but not unfrequently they are irregular in form, and would seem to have suffered mechanical injury. Sometimes the crystals are seen to be split along planes of weakness, and masses of the material which has crystallized as augite have been forced into the cracks (see Plate VII. fig. 2).

Examples also occur of porphyritic varieties of the ophitic dolerites; but these, I think, are less frequent than the dolerites with porphyro-granulitic structures. There is one very remarkable variety of the porphyritic structure exhibited by the ophitic dolerites of Fair Head, Co. Antrim, which I shall describe more particularly in the sequel.

Beautiful examples of the porphyro-granulitic structure are exhibited by the intrusive dolerites in many parts of the area under consideration. I may especially instance those of Dun-da-gu in the Isle of Mull, of Ardnamurchan, and of the Carlingford Mountain in Ireland. Similar structures are exhibited by some of the massive lavas, such as that of Ru Geur in the Isle of Skye.

Porphyritic basalts are extremely common in the area; indeed they preponderate over non-porphyrific varieties; in other words the majority of basalts contain, scattered through their ground-mass, certain crystals which are distinguished by their larger size, and frequently by other characters also, from those forming the ground-mass itself. The mineral which usually occurs in porphyritic crystals is the felspar; but olivine in large grains is sufficiently frequent; while augite, so abundant as a porphyritic constituent in the basalts of other petrographic provinces, seldom or never occurs in that form in our rocks.

At a point on the north-east side of Mull, between Tobermory and Ardnacroish, I found a basalt containing porphyritic felspar crystals which were no less than two inches across. The easy cleavability of the porphyritic crystals, and the toughness of the base in which they were imbedded, made it quite impossible, however, to obtain really representative hand-specimens of the rock.

Porphyritic Tachylytes.—In some of the basalt-glasses of this district, as has been already pointed out*, porphyritic crystals, not only of felspar and olivine but also of augite, occur not unfrequently. The corroded appearance of such crystals has been already described.

4. *The Glomero-porphyrific Structure*.—In the remarkable ophitic dolerite of Fair Head, Co. Antrim, we find an example of a structure which, so far as I am aware, has not hitherto been described, and to which the above name may be applied. The base is an ordinary ophitic dolerite, but scattered through this base we find groups of anorthite- and olivine-crystals which appear like scattered fragments of an olivine-anorthite rock or troctolite (see Plate VII. fig. 3). The relations of the anorthite and olivine in these inclusions, which vary from one tenth to one third of an inch in diameter, is similar to that which is so well known as characterizing the Forellenstein or troctolite. The olivine is not altered to magnetite along the cracks, as is so frequently the case in the troctolites, but the anorthite contains a large number of secondary inclusions. I have not been able to detect any clear indications of change along the edges of these groups of crystals, where they are in contact with the enclosing ophitic dolerite, but the felspars are certainly traversed by an enormous number of fine cracks; this is the more striking inasmuch as the associated olivines are almost unaltered, and do not send out radiating processes of serpentine into the felspars, as is so frequently the case with the troctolites in which the process of serpentinization of the olivines has commenced (see Plate VII. fig. 3).

The only approach to this glomero-porphyrific structure with which I am acquainted is that exhibited by some dolerites—for example, those of Carboniferous age described by Mr. Allport †, in which we find radiating groups of felspar-crystals sometimes associated with large augites, both of these minerals showing some characters which distinguish them from the mass of the crystals in the rock. Those who regard the enclosures composed of olivine,

* Quart. Journ. Geol. Soc. vol. xli. (1885) p. 444, plate xiii.

† Quart. Journ. Geol. Soc. vol. xxx. (1874) p. 529, &c.

enstatite, augite, &c., which are found in some basalts as having separated at some period from the magma, out of which the enclosing basalt was itself formed, may regard these as examples of the glomero-porphyritic structure on a gigantic scale.

When the character of porphyritic crystals is compared with that of the same mineral forming a part of the ground-mass of the rock, we usually find that the porphyritic crystals are of more basic composition. Thus, in a dolerite containing labradorite-crystals in its base, the porphyritic crystals appear to be anorthite; this is proved both by the extinction-angles of the different felspar-crystals, and by the application to them of Szabó's chemical test. The same fact has been well illustrated in the case of the dolerites of Iceland by M. Bréon*. In the same way, basalts which contain porphyritic crystals of labradorite sometimes appear to have a more alkaline species of felspar (andesine or oligoclase) in their base.

It has frequently been remarked that the enclosures of glass in porphyritic crystals have a different character from the glass of the ground-mass of the rock. But while we find this to be the case in some of the rocks we are now considering, we also find evidence that the material of the ground-mass has in many cases penetrated into cracks and eaten into the surfaces of the porphyritic crystals. There appears to be evidence that at the time when this took place, the materials of the ground-mass had already in part crystallized. Thus we sometimes find crystals of magnetite or granules of augite which seem to have been mechanically forced between the plates of a porphyritic crystal of felspar.

5. *Micro-pegmatitic (?) Structure.*—There is yet another structure not unfrequently displayed by these rocks which is worthy of very careful study. In 1874, Allport drew the attention of geologists to a very interesting structure, which he figured from the Rowley-rag†. The pyroxene and felspar are here seen intergrown in such a manner that the former constitutes a number of rays diverging from a centre in the midst of the felspar-crystals. I have found beautiful examples of this structure in a coarse dolerite from near Bombay, for specimens of which I am indebted to Mr. A. P. Young, F.G.S., but have not noticed it in any of the rocks now under consideration. For a similar intergrowth of minerals, H. Fischer proposed the name of “*ocellar structure*,” while in 1881, F. Becke described a number of remarkably interesting cases of the same character under the name of *centric structure*.

Among the rocks exhibiting what Michel-Lévy calls *micro-pegmatitic structure*, and Rosenbusch *granophyric structure*, there are some which exhibit a plumose and radiating arrangement of the two intergrown minerals. M. R. Bréon has figured a beautiful example of this kind from Iceland under the name of *microgranulitic*

* Notes pour servir à l'étude de la Géologie de l'Islande et des Iles Foeroe (1884), p. 18, pl. ii. fig. 2.

† Quart. Journ. Geol. Soc. vol. xxx. (1874) p. 549, pl. xxxiv. fig. 28.

structure* ; and the same structure is frequently exhibited in the felspars of the gabbros of Mull (see Plate VII. fig. 8). There are strong grounds for believing, as Professor R. D. Irving remarked in 1883, that some structures of this kind are of secondary origin in the rocks † ; others, it can scarcely be doubted, are original. In rocks from Portsoy I have found clear evidence of the origin of structures of this kind, through alteration of the felspar (see Plate VII. fig. 9).

As these structures are much better exhibited in the more acid rocks from the same district, I think it will be better to reserve the full discussion of them until I come to the description of the latter.

VIII. GEOLOGICAL RELATIONS OF THE ROCKS EXHIBITING THE SEVERAL STRUCTURES.

When we come to study in the field the positions and relations of the rock-masses exhibiting the several structures above described, some very important conclusions are suggested to us.

The granitic structure is confined to the gabbros, and occurs only in the central portions of the largest of the extruded masses. The very coarse-grained and porphyritic forms occur in the central parts of the great mountain-masses of Skye and Ardnamurchan, or occasionally as contemporaneous veins traversing finer-grained rocks of the same class in these and the other districts.

From the granitic types, through less perfectly crystalline forms, to the vitreous there is, as I have always insisted, the most perfect gradation. But the careful study of a large number of microscopic sections, cut from rocks the positions and relations of which have been carefully determined in the field, brings out a remarkably interesting fact. The passage from gabbro to glass takes place not along one line simply, but along two distinct and parallel ones.

Sometimes we find about the edges of the great mountain-masses the felspars losing their broad platy character and exhibiting lath-shaped sections. In these cases the felspars are found becoming more and more completely enclosed in the pyroxenes, until the most perfect ophitic structure is produced. It is possible in this way to illustrate in the completest manner the transition from the most perfect gabbro to the most typical ophitic dolerite (see Plate IV. figs. 3, 5, & 7, and Plate V. fig. 1).

But at other times the change from gabbro to dolerite takes place in a totally different way. The felspars, as in the last case, exchange their broad platy forms for narrow prismatic ones with lath-shaped sections ; but these, crowding together into an intercrystallized mass, have had developed in their midst a number of grains of pyroxene and olivine, everywhere distinguished, as seen in section, by their curvilinear outlines. In this way we have a granulitic dolerite formed (see Plate IV. fig. 8, and Plate V. fig. 2).

Let us now inquire if there is anything in the geological position

* *Loc. cit.* p. 33, pl. vi. fig. 2.

† U. S. Geological Survey, Monograph V. The Copper-bearing Rocks of Lake Superior (1883), p. 114, pls. xiv., xv.

and relations of the rock-masses which exhibit these very dissimilar types of structure which may account for their differences. It has been suggested that the ophitic structure is characteristic of, and limited to, rock-masses which are intrusive in other rocks. While, however, it is certain that the most perfect illustrations of ophitic structure on the grandest scale are found in such splendid examples of intrusive sheets as those of the Shiant Isles and Portrush, yet it is an undoubted fact that many of the larger and more massive of the lava-currents of the district exhibit this same structure in a fairly well-marked manner—every gradation, indeed, existing between these ophitic and semi-ophitic lavas and the more common type, which is, as we shall see, distinctly granulitic or porphyro-granulitic. But in some of the smaller masses, both lavas and dykes, we find this beautiful structure admirably displayed though on a very minute scale. These constitute the *micro-ophitic* basalts (see Plate V. figs. 3, 5, 7).

The great mass of the doleritic and basaltic lavas, however, exhibit different stages of the granulitic and the porphyro-granulitic types. From the granulitic dolerites, which we have described, through the micro-granulitic forms, we get every gradation—the granular elements, pyroxene, and olivine becoming smaller and smaller, as do the lath-shaped feldspars, till all are reduced to the condition of microlites; at the same time the quantity of glassy matter increases, till we pass from the ordinary basalts to the magma-basalts (see Plate V. figs. 2, 4, 6, 8).

If we now turn our attention from the more crystalline to the compact and vitreous varieties of the basalts (magma-basalts), we find the two parallel series of differences to which we have already referred. It is in the glass of basalt forming *dykes* that we find the best examples of the skeleton-crystals of magnetite with those of augite and feldspar (see Plate VI. figs. 1, 3, 5, 7); while in the basalt of lava-streams the glass is filled with rounded microlites of augite, detached grains of magnetite (magnetite dust), and short prismatic microliths of feldspar (see Plate VI. figs. 2, 4, 6, 8). Between these two types there are, of course, all intermediate stages; but I have no hesitation in affirming, as the result of prolonged and repeated studies of these rocks in the field, that the basalt containing a glass with skeleton-crystals is especially characteristic of the dykes, while varieties in which the microliths are short in form and often rounded in outline, constitute the type which is usually exemplified in the lava-streams.

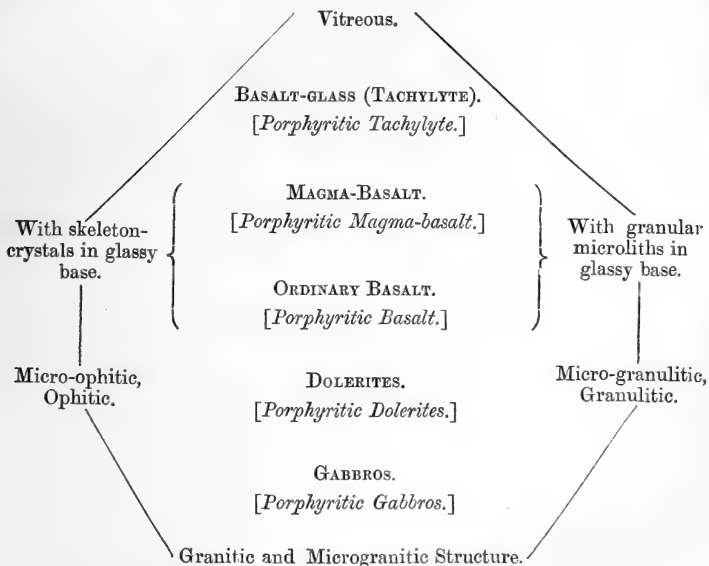
The tachylytes of the district are only known to occur as “selvages” to dykes. In these tachylytes, as has been already shown, skeleton-crystals abound. There is one interesting type, that of the Beal, near Portree, in Skye, where a magma-basalt, full of skeleton-crystals, passes at the edge of the dyke into a glass in which the magnetite is separated only in the form of cloudy patches, sufficiently dense to render the mass almost perfectly opaque.

Porphyritic varieties occur both among the rocks forming intrusive masses and in those constituting lava-streams. While they are com-

paratively rare and even exceptional among the most deeply-seated rocks (gabbros), they become more and more abundant as we pass to less highly crystalline forms, till in the basalts they form the rule rather than the exception. It may be fairly said that basalts are rare in which evidence of *at least* two periods of consolidation is not represented among their constituents—the porphyritic crystals of felspar or olivine or of both those minerals, and the glass filled with microliths.

To sum up these results, we may say that among these basic rocks the only type of rock *absolutely* characteristic of intrusive masses is the granitic; but ophitic varieties and varieties with skeleton-crystals in their base abound in, though they are not confined to, intrusive rocks; while rocks of granulitic structure and those with short and rounded microlites in their ground-mass are especially abundant among the lavas.

The relations of the several rock-structures which we have been describing to one another are illustrated in the following table.



IX. ORIGIN OF THE STRUCTURES.

The facts now passed in review cannot fail to suggest to every one who carefully considers them an explanation of the origin of the several structures we have been describing.

The granitic structure exhibited by the gabbros is evidently the result of the consolidation of a magma at a great depth from the surface, where almost uniform temperatures are maintained during enormous periods of time, and where the pressure is also very great. Owing to the low conductivity of these rocks their rate of cooling-down in such vast mountain-masses must be almost infinitely slow,

and similar conditions can never exist, even in the largest mass extruded at the surface; thus it comes to pass that we never find lavas assuming the form of gabbro or granite.

The ophitic type is clearly found in masses which are of considerable dimensions,* though not so large as those forming the gabbros, in which the rate of cooling is somewhat more rapid and the pressure less than in the case of the latter. But the geological relations of these rocks also indicate that the ophitic structure is produced where the molten mass is in a state of perfect *internal equilibrium*; that is to say, where there is no kind of movement whereby strains and tension can be produced in the viscous mass during its consolidation. Nowhere can such conditions exist in such perfection as in the great masses of lava, sometimes hundreds of feet in thickness, and extending over many square miles in area, which are found intruded between strata. When the injection has once taken place, such a mass must remain in a state of almost perfect internal immobility. In some of the large lava-currents, when a solid crust has formed over them and no further movement can take place, the conditions seem to be almost equally favourable for the formation of this structure, and accordingly we find an ophitic structure, though of a somewhat less perfect character, arising under such conditions (see Plate V. figs. 3, 5).

In masses of molten rock where internal movements accompany the crystallizing process, a "*granulation*" of the pyroxene and olivine is the result. Instead of the formation of large crystals, we have an agglomeration of grains with more or less marked curvilinear outlines, presenting every possible orientation. That this action really takes place can be shown in gabbros and ophitic dolerites in which movement has taken place towards the end of the process of solidifying (see Plate VII. fig. 4). In these cases the pyroxene crystals are found surrounded by a zone of *granulated* pyroxene. It is when this crystallization goes on in a mass not in a state of internal equilibrium, that the *granulated* structure is developed; and the passage from the granulitic and micro-granulitic dolerites, which are holocrystalline, through the various types of basalt, in which more and more of the vitreous base appears, is as perfect as in the parallel case of the ophitic rocks (see Plate V. figs. 2, 4, 6).

Of course, as might be expected, we find every gradation between these two parallel series of rocks, ophitic rocks passing insensibly into granulitic ones.

The mode of separation of the magnetite, felspar, and augite from the glassy base of the basalt appears to be equally determined by the existence of equilibrium or otherwise in the midst of the cooling mass. In dykes especially, and in some lava-streams, the entire absence of any internal movements in the cooling mass appears to be conducive to the formation of delicately branched rods or skeleton-crystals of magnetite, with the long transparent rods bifurcating at both ends, which seem to be skeleton-crystals of augite, felspar, or olivine (see Plate VI. figs. 1, 3, 5, 7). But in the majority of cases, we find microlites of rounded forms of augite and magnetite

with short prismatic microlites of felspar. These microlites seem to represent on a very minute scale the rounded crystals of the granulitic rocks, and, like them, appear to indicate that the whole mass was subjected to internal movements while crystallization was taking place in it (see Plate VI. figs. 2, 4, 6, 8).

Coming to the most highly vitreous forms, we find the same distinction. In some cases we see the whole of the glass filled with delicate black rods (trichites) or beaded rods (margarites), with very minute transparent crystallites (belonites &c.). But in other cases the whole glass is filled with clouds of excessively minute, rounded particles of magnetite ("magnetite dust"), which renders it nearly opaque. In the case of the Beal dyke near Portree, in Skye, we find the rod-like crystallites at a short distance from the edges; but at the actual edges, where some friction may be supposed to have occurred, the rods resolve themselves into magnetite dust.

With respect to the origin of the porphyritic crystals, it may be pointed out that while we may in some cases regard them as having separated from the magma, when it existed at a greater depth from the surface than when the ground-mass crystallized, in other cases there appears to be a difficulty in applying this mode of explanation.

In some instances the mechanically injured condition of the crystals and other appearances strongly suggest their actual transport from below in the midst of the materials of the surrounding ground-mass. But in others the porphyritic crystals exhibit zoned structures and other characters not found, perhaps, in the deeper-seated rocks of the class in the same area. May we not in these cases explain the phenomena in the way suggested by M. Michel-Lévy, by the consolidation having taken place at two different periods? It is not difficult to imagine conditions which would bring about such a result. If, for example, a mass of igneous materials were in a liquid state at a great depth from the surface, the conditions might be favourable to the separation of a felspar of a given composition from the magma. The continued abstraction of certain elements from the base would alter the composition of the surrounding magma, and this would modify slightly the conditions causing the successively formed zones of the crystal to vary slightly in composition. But if a fissure were formed above such a molten mass, then the pressure upon it would be greatly and suddenly relieved, even though no actual movement occurred in the deeper-seated portion. Under the entirely new conditions thus originated, the magma surrounding the zoned crystals already formed might be induced to crystallize in a totally different manner, the order of the separation of the minerals and the forms and relations of their several crystals being determined by these new conditions.

It might at first sight appear that the unaltered or the corroded appearance of the porphyritic crystals would afford a test as to whether those crystals had consolidated in the midst of the rock in which they are now formed or had been transported from a deeper-

seated mass. But when we bear in mind that a crystal is only stable so long as it remains under the exact conditions which surrounded it when it was formed (and this conclusion the researches of Klein and others upon boracite, leucite, &c., give us ample ground for assuming), then it may be anticipated that the corrosion of a porphyritic crystal may not only be due to a change in the composition of its enveloping magma, but can be equally brought about if the crystal and the magma are exposed to new conditions.

Without attempting, then, to decide the mode of origin of the porphyritic structure in each individual instance, we have sufficient grounds for inferring that while, in some cases, the porphyritic crystals have clearly undergone transport, and may have been brought up from a more deeply-seated source, in others all the phenomena point to consolidation of the materials of the rock at two different periods, when the mass was subjected to dissimilar conditions.

The glomero-porphyratic structure may have originated either in the one way or the other. A troctolite may have been broken up, and its fragments have been included in a magma which crystallized as an ophitic dolerite; or the anorthite and olivine may have separated around certain centres, and new conditions have induced the crystallization of the rest of the magma as an ophitic dolerite.

X. PRINCIPLES WHICH HAVE GOVERNED THE CRYSTALLIZATION OF THE ROCKS.

Many petrographers have endeavoured to determine the exact order in which the crystals have been developed in an igneous rock by observations based on the enclosure of individuals of one species in those of another species, or of their mutual interference during growth. Professor Rosenbusch has lately insisted on the great value and importance of this kind of investigation. He has called especial attention to the fact that there is a remarkable contrast between the rocks of basic composition and those of more acid character, in the order in which their constituent minerals seem to have separated from their respective magmas*.

In the intermediate and acid rocks, the more basic minerals separate out first, so that the glassy ground-mass is continually acquiring a more acid composition, by the extraction of the bases faster than the silica. But in the basic rocks, we find that this rule does not hold good.

The truth of this statement is admirably illustrated by the rocks we are now studying. In the gabbros and ophitic dolerites it is evident that the first mineral which crystallized out (after the apatite) was the felspar, and not the ferro-magnesian silicates.

But a careful study of the whole series of these British and Irish rocks brings to light some very important principles, which seem to govern the crystallization of the basic magmas. It is evident that the separation of the different classes of minerals is not determined, solely, by chemical affinities. The conditions under which consoli-

* Neues Jahrb. für Min. &c., 1882, ii, pp. 1-16.

dition has taken place have certainly had not a little to do with the order of crystallization of the minerals of the rock.

Before any satisfactory conclusion can be arrived at concerning the order in which the several minerals of a rock have crystallized from the magma, we must allow for two possible sources of error in reasonings of this kind:—

First we must determine with accuracy which are the *original* minerals of the rock, and carefully distinguish them from such as are of *secondary* origin.

Secondly it must be borne in mind, as has been so justly insisted upon by MM. Michel-Lévy and Fouqué, that there may be several distinct periods of consolidation of the minerals in a rock, and that some crystals may even be derived, ready formed, from a foreign source.

Bearing these considerations in mind, I have been able to arrive at the following conclusions with regard to the rocks we are now studying:—

The oxides of the iron-group of metals (iron, manganese, chromium, nickel, and cobalt) behave quite differently in basic magmas which have consolidated slowly and under pressure, and in the same magmas cooling at the surface. This is shown by the fact that in the most deeply seated magmas there are no *original* spinellids (magnetite, chromite, or picotite), but the whole of the oxides of the iron-group exist in union with silica, either as pyroxenes or olivine. The careful study of the perfectly crystalline types of all these rocks from different portions of the area under consideration shows that magnetite, when present in them, is always a *secondary* product resulting from the “schillerization” of the olivine or the pyroxenes. I find that Prof. von Lasaulx, from his examination of a series of the Carlingford gabbros in 1878, was convinced that the magnetite in his specimens was of secondary origin*.

And a critical examination of the whole series of these rocks shows that as the cooling becomes slower and the pressure less, the quantity of the oxides of iron separating as magnetite progressively increases. In some of the less highly crystalline gabbros and in the dolerites, small quantities of original magnetite can be detected; in the basalt it increases in amount; in the magma-basalt the whole base of the rock is thickly sown with skeleton-crystals or dust of magnetite; and in the tachylytes it sometimes becomes so abundant as to render the rock completely opaque even in the thinnest sections.

It follows, as a necessary corollary from this proposition, that the pyroxenes and olivines which separate from a magma when it is deep-seated must be more highly ferriferous than the same species of minerals crystallizing from the same magma nearer the surface. And there are many facts which appear to support this conclusion. It is the highly ferriferous character of the deep-seated olivines which seems to facilitate their alteration into opaque masses by schillerization. Another conclusion which may be drawn from the study

* Tschermak's *Min.* und *Petr. Mitth.* vol. i. (1878), p. 429.

of these rocks is, that the conditions of consolidation have variously influenced the relative order of crystallization of the ferro-magnesian silicates (pyroxenes and olivines) and the aluminous-alkaline silicates (felspars). In the gabbros, the mutual interferences of the several minerals seem to indicate an almost simultaneous crystallization; but in all cases, so far as I have seen, the advantage in the matter of priority seems to remain with the felspars; for when crystalline faces are developed they are always those of felspar individuals. In the dolerites, and especially in those of the ophitic type, the prior crystallization of felspars to both pyroxenes and olivines is a very obvious feature. In the basalts it is often difficult to say whether the one class of minerals has the advantage or not of the other as to priority in crystallization; but it is certain that skeleton-crystals and microlites of both groups of minerals may be seen in course of development, side by side, in the same glassy magma.

XI. ALTERATIONS WHICH THE ROCKS HAVE UNDERGONE.

In the facility with which their constituent minerals undergo change, the basic rocks are perhaps only second to the ultra-basic ones. Much of the confusion which has prevailed concerning the gabbros seems to have arisen from the circumstance that, in the majority of cases, it is the highly altered products of these rocks which have been studied—materials like saussurite-gabbro, wurlitzite, and variolite, in which perhaps not one of the original mineral constituents remains. In such rocks the felspars are found changed into saussurite (zoisite &c.), the augite into hornblendes (smaragdite, actinolite, &c.), and the olivine into magnetite and serpentine. Still further changes may have taken place by which the rock is converted into a hornblendic schist or gneiss. In the same way the less perfectly crystalline varieties are found altered—the dolerites into “diabases,” the basalts into “melaphyres,” “palatinites,” “basaltites,” and finally into “wackes.” Careful study under the microscope often shows that the whole of the minerals which at present make up the rocks are pseudomorphs of or derivatives from the minerals of rocks similar to those described in this memoir.

Although the highly altered igneous rocks are usually found in connexion with the more ancient geological sediments, yet it would be a mistake to infer that the amount of alteration which an igneous rock has undergone is any criterion of its geological age. Some of the Tertiary rocks in the district we are describing are found in the most highly altered state; scoriaceous basalts are found converted into crumbling amygdaloidal rocks, their cavities filled with zeolites, chlorophæite, chalcedony, or calcite. Sometimes, indeed, the whole is converted into a dark green clay or “wacke.” Conversely, we sometimes have the good fortune to find in the midst of a mass of a very ancient igneous rock portions which have escaped the extreme change, and in which the original and characteristic minerals and rock-structures may be readily made out.

The great value of the examples of the basic rocks in the district

we are now describing arises from the circumstance that we are able to study in them the *incipient* stages of the several transformations which their minerals undergo. From examples in which the minerals are absolutely fresh and unaltered, we may trace every gradation into the most highly altered forms. All those alterations of minerals, which have been so well traced in the case of the older rocks by Mr. Allport* and Professor Bonney, may be as clearly, if not as frequently, found exemplified in the case of these rocks of Tertiary age.

There is one point which comes out from these studies which must be carefully borne in mind. The same mineral species does not always exhibit the same degree of *chemical instability* or liability to be acted upon by chemical agents. For this we might perhaps be prepared by the circumstance that the behaviour of different varieties of the same mineral species with artificial solvents also varies in a very remarkable manner. Thus different varieties of olivine have been shown to differ in the most striking manner in their solubility in acids. Perhaps the most common rule is that the olivine is the most easily altered constituent in the basic rocks, then follows augite, and lastly felspar †. But there are cases in which the rock appears to contain an abnormally unstable augite or felspar, and this sequence of decomposition is no longer maintained. There are even some picrites, like those of Central Rum, in which the adventitious crystals of anorthite appear to be of such a singularly unstable character that they have been converted into zeolites and other decomposition-products, while the augites, enstatites, and olivines show no sign of change. Even in the same mineral in a mass of rock, among crystals which exhibit no recognizable difference, we may find some undergoing extreme alteration, while others around them remain quite unchanged. What are the subtle causes of the different degrees of susceptibility to the same chemical forces in different crystals of the same mineral, it is, in our present state of knowledge, impossible even to suggest.

The alterations which the minerals of these rocks undergo are of the most varied kind, and are evidently due to the action of different causes, among which the five following may perhaps be reckoned as the chief:—

§ 1. *Action of surrounding Magma upon Crystals.*

The progressive acidifying of the glassy base of a rock by the crystallizing of its more basic constituents is a characteristic of the acid and intermediate classes of rocks, rather than of the basic ones. Hence it is in the former rather than in the latter that we notice those very conspicuous changes of the exterior portions of crystals where they have been in contact with the enveloping acid material.

* See Quart. Journ. Geol. Soc. vol. xxx. (1874) pp. 529-567.

† Professor Bonney, who has paid much attention to this question, however, informs me that, according to his experience, among igneous rocks of different areas, the felspars, as a general rule, succumb to weathering-action before the augites.

But inasmuch as a crystal formed under one set of conditions may be in a state of instability when those conditions are altered, we frequently find the porphyritic crystals in the basic rocks exhibiting evidence of this kind of action.

It is in the basalt-glasses (tachylytes) and in the magma-basalts which approach these in character that the most striking effects of this kind are exhibited. As already pointed out *, the porphyritic crystals of felspar, augite, and olivine in these rocks are completely honeycombed by penetrations of glassy material identical in character with the surrounding ground-mass. These porphyritic crystals are certainly transported ones, and have been brought from below, where they were formed under totally different physical conditions. Enveloped in a mass of molten glass, differing in composition from that in which they were formed, it is not surprising to find that they have yielded to a great extent to the solvent action.

It is interesting, as bearing upon the theory of schillerization, to notice that this solution of crystals often takes place along definite crystallographic planes; that is to say there are certain planes of chemical weakness in the crystals, a fact in complete harmony with the phenomena of the "Aetzfiguren" and of "schillerization."

§ 2. *Action of Solvents under Pressure (Schillerization).*

This subject has been fully discussed in a former paper †. It is there shown that as a result of the solvent action operating along cracks or lines of strain, and also in certain planes of chemical weakness, in crystals, secondary enclosures containing liquids or solids are formed. Further, by the same agent the felspars acquire aventurine and chatoyant properties, the pyroxenes are converted into "schiller" varieties, and the olivines are studded with stellar inclusions, and finally become so filled with particles of magnetite as to assume a black and opaque appearance.

That these phenomena are due to deep-seated action is shown by the fact that the schiller varieties of augite (known as diallage and pseudo-hypersthene) and the "schiller" varieties of enstatite (known as bronzite and hypersthene) are confined to the highly crystalline and deeply-seated rocks; and it is in such situations only that we find the similarly altered forms of olivine and felspar. But as solvent action at the surface may be local and partial in its action, so is it at great depths; and we find side by side in these deep-seated rocks crystals which are more or less highly schillerized and others quite free from this kind of change.

That *schillerization* is the result of changes which have taken place in crystals long after their formation, and that schillerized minerals are therefore *altered* products, is proved in many ways. The schillerizing process can be shown to have originated either from the surfaces of crystals or along lines of accidental fissures traversing the crystals, and the materials which are contained in

* Quart. Journ. Geol. Soc. vol. xli. (1885) p. 444.

† *Ibid.* vol. xli. (1883) p. 383.

the negative crystals are decomposition-products—mixtures of various hydrated oxides.

In the most deeply seated gabbros, like those of Skye, Ardnamurchan, and the Carlingford mountains, the form of augite known as pseudo-hypersthene abounds. This is a variety in which the schillerizing process has been set up along two or three mutually intersecting planes. In gabbros of less deeply seated origin, as on the outskirts of the larger masses, and in the centres of those of smaller dimensions, as in Mull, Rum, and St. Kilda, the form of augite with schillerization along one plane only, which is known as diallage, abounds; and there is every gradation from this diallage into ordinary augite as we examine portions that have consolidated nearer the surface (see Plate IV. figs. 5, 6).

There are precisely the same relations between the rocks containing the forms of enstatite known as hypersthene and bronzite respectively.

§ 3. *Action of Steam and other Gases at the Surface.*

In a district which has been subjected to such an enormous amount of denudation as that which we are considering, it can scarcely be expected that many of those chemical changes of the surfaces of lavas, which are so familiar to all students of volcanic districts, should be exhibited. There is indeed distinct evidence that in many cases the surfaces of the old lavas had weathered into a soil, and sometimes that they had suffered considerable denudation before they were covered up by the later flows. Consequently the preservation of the surface-products formed by the action of the escaping steam and other gases upon one another and upon the materials of the lavas through which they escape must be of very rare and exceptional occurrence.

Nevertheless, traces of this kind of action do occur in the district we are describing. In some of the basalts the vitreous matter of the ground-mass is seen to be converted into the hydrated glass which has received the name of *palagonite*. Such basalts may be conveniently termed “palagonite-basalts,” and examples of them occur in Mull and some other of the Western Isles of Scotland.

The infilling of the cavities formed by the escape of bubbles of gas in the basaltic lavas, whereby a scoriaceous basalt is converted into an amygdaloid, is not improbably due, in part at least, to the chemical actions set up by the steam and other gases escaping through the lavas on their way to the surface. It is a very noteworthy circumstance in connexion with these rocks, that where the amygdaloidal kernels abound, the mass of the rock has undergone the greatest amount of decomposition. Thus, in a lava in which the central and compact portion shows but little signs of decomposition, except in the serpentinization of the olivines and a partial alteration of the felspars, the scoriaceous upper and under portions will have undergone the most complete alteration into a soft crumbling mass. The collection of liquids and gases in these cavities has converted them into laboratories of synthetic mineralogy. The several minerals and glasses of the surrounding rock have

served as materials for these natural experiments, and have been variously acted upon, so that there have grown up in the interior of the cavities, crystals of the zeolites, chlorophæite, epidote, quartz, calcite, and other minerals, with layers of chalcedony and other crypto-crystalline materials. The removal of material from the rock has often rendered it soft and friable, and when examined by the aid of the microscope it is seen to have lost its characteristic structure and mineral characters. Not unfrequently secondary quartz or calcite is found to have been introduced into the substance of the rock, giving it new cohesion, while the colour of the rock has been changed from black to various shades of reddish brown through the partial peroxidation and hydration of the magnetite. Some of these altered rocks are in no way distinguishable from the amygdaloidal melaphyres and similar rocks which have usually been regarded as being characteristic of the older geological periods.

§ 4. *Action of Atmospheric Agents (Weathering).*

If the action of escaping steam and other gases on volcanic rocks is only imperfectly exemplified in the district we are describing, nowhere can we find better examples of the changes produced by water percolating from the surface and carrying with it oxygen, carbonic acid, and other substances in solution. It is not always easy to separate the results of the two kinds of action from one another or from the effects of the action of deep-seated solvents, though their products are in some cases very strikingly contrasted.

The felspars, as the result of weathering action, exhibit every degree of kaolinization, owing to the breaking up of the silicates of the alkalis and the alkaline earths, and the removal of their products in solution, this action being accompanied by the hydration and recrystallization of the silicate of alumina. Every stage of this alteration can be traced, from a slight clouding of the transparent felspars to their passage into white and opaque pseudomorphs. The materials left behind in these pseudomorphs may recrystallize as zoisite or other complex silicates, which have received the name of "saussurite." In some cases the breaking up of the felspar materials is attended with the separation of considerable quantities of silica, which crystallizes as secondary quartz; such secondary quartz is found in many of the altered gabbros of the district.

The augites, both the non-ferriferous and the ferriferous varieties, undergo similar very interesting series of change. Sometimes the nearly colourless varieties acquire a brown or purplish tint on their exterior portions, and this change of colour is seen extending inwards in different crystals till the original colour is nearly lost. It is evident from these facts that the colour of augite-crystals, as seen by transmitted light, is a character upon which but little dependence can be placed. The conversion of a very small proportion of the iron-salt from the ferrous to the ferric state is probably sufficient to produce considerable changes in tint. In some cases, however, it is quite possible to discriminate between the original and

normal tint of the augite in a rock and the unequally distributed tints acquired by alteration.

Sometimes the augites, both the pale-coloured and the brown varieties, are found undergoing paramorphic change into hornblende. In these cases the *first* change seems to consist in the acquisition of the characteristic colour and pleochroism of the hornblende. Thus we find the purplish-brown augite of the ophitic dolerite of the Shiant Isles (Plate V. fig. 1) assuming the yellowish-brown tint and the strong pleochroism of hornblende, while the cleavage-cracks and other features of the augite still remain. (See *antè*, p. 65, *footnote*.) But sometimes a brown augite passes into a green hornblende and *vice versâ*; and not unfrequently crystals of the same augite may be found passing into both green and brown hornblende. This subject has been carefully studied in many of the older rocks by Professor Bonney, F.R.S.* When the augite has by schillerization been converted into diallage, the changes produced by superficial action may be somewhat modified. The augite, from which much of the iron has been separated, shows a great tendency to pass into the bright green actinolitic varieties known as smaragdite. So great is this tendency that there are cases in which gabbros, with olivines only slightly serpentinized, have their diallage-crystals bordered by fringes of smaragdite. The first stage of this change, which is accompanied by the separation of calcic carbonate and other decomposition-products along the planes of foliation of the diallage, leads to the formation of the beautiful varieties known as "green diallage."

But in other cases the change of the augite takes place in an entirely different manner. The whole mass of each augite-crystal is seen passing into the green structureless material known as "viridite;" incipient crystallization in this viridite not unfrequently leads to the formation of vermiform aggregates like those so often seen on a larger scale in the minerals of the chlorite group. Eventually, however, the whole of the viridite substance may acquire the pleochroism and cleavage of hornblende. As the product of this kind of change is uralite, the change may be called "uralitization." There are thus two entirely different methods by which the augites are converted into hornblende, the *direct* paramorphic transition and the *indirect* uralitization; but why the change sometimes takes place in the former way and at other times in the latter, I have as yet found no clue for determining.

When a schillerized mineral undergoes alteration by weathering, the characteristic secondary enclosures sometimes remain unchanged. In the case of the diallages of some of the Mull Gabbros, so much titanoferrite is present in their secondary enclosures that the whole acquires, by weathering, the peculiar white and opaque appearance of leucoxene or titanomorphite (see Plate VII. fig. 6).

The products of the change of enstatite are, in most cases, quite different from those of augite, and more nearly resemble the materials produced by the alteration of olivine. This probably

* Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 254, &c.

arises from the fact that the enstatites, as a rule, contain a larger proportion of the magnesian silicates than do the augites. The traces of the secondary foliation of the enstatites are also visible in their alteration-products, in the form of plates and patches of iron-oxides arranged in parallel bands.

The olivines by simple hydration pass into serpentine; and this change commences along the surfaces of the grains and penetrates along the lines of cracks which traverse them; from these lines it extends inwards till not a vestige of the original olivine is left. When, as in the more deeply seated rocks, magnetite has been separated by schillerization, this magnetite remains in the serpentine and, by the forms it assumes, often affords a clue to the nature of the original mineral. The hydration of the olivine and its consequent conversion into serpentine is attended with an increase in bulk of the individual grains; in consequence of this, when, as in troctolite (Forellenstein), the grains of olivine are surrounded with felspar-crystals, these latter become cracked, and the fissures thus produced are injected with the serpentinous material. This effect is admirably seen in some cases where each grain of olivine is found to be surrounded by a radiating series of branching fissures, each of which is filled with green serpentinous material (see Plate VII. fig. 7). Even in the ordinary gabbros, where no such regular radiating cracks can be detected, the expansion of the serpentine has sufficed to cause its injection into all the accidental fissures and openings in the surrounding minerals.

The change of titanoferrite into leucoxene (or titanomorphite) is well known, and is frequently exemplified in these rocks. The chromite and picotite by their decomposition give rise to chromates of a very rich and characteristic green tint.

The glass of these basic rocks through the action of atmospheric waters is often seen to be converted into a green substance very distinct in appearance from the brown product (palagonite) resulting from the action of heated waters on the same glass.

As the result of these changes in their constituent minerals, the several members of the basic series are converted into new rocks. The gabbros pass into saussurite-gabbros, wurlizites, or variolites; the dolerites assume the characters of some of the rocks known as diabases, and the basalts acquire the peculiarities of melaphyres, basaltites, and palatinites. Each of these rocks in turn may, by still further atmospheric change, be reduced to masses of dark-coloured clay or wacké. Of course the slightly altered forms of these rocks are more common in the formations of Tertiary age, and the highly altered forms among older deposits; but neither the one nor the other can be regarded as *characteristic* of any particular geological period.

§ 5. *Effects of Crushing Movements in Rock-masses.*

It is only necessary in this place to mention this last and very potent cause of change in the rocks of the basic series. While the action of the former causes is, in the main, destructive, that of the

last mentioned is reconstructive. The effect of schillerization and weathering is to bring about a destruction of the original crystals and an admixture of their materials. But under the influence of great crushing movements rearrangement and recrystallization is brought about, the new minerals thus formed arranging themselves in more or less distinct and parallel folia, and the rock becoming a schist. A very instructive example of this action has lately been described by Mr. Teall as occurring in a dyke at Scourie*. But in the district we are now describing, where no such great movements have taken place since the formation of the rocks, changes of this kind are not exemplified.

XII. SUMMARY OF RESULTS.

The igneous rocks of Iceland, the Faroe Islands, the Western Isles of Scotland, and the northern part of Ireland, present a striking similarity in character, and belong to the same petrographical province. Among the salient characters which distinguish the basic rocks of this province may be mentioned the prevalence of the ophitic structure, as well as the absence of porphyritic crystals of augite or hornblende, and of enclosures of olivine, enstatite, and augite.

That the whole of these rocks were erupted during the Tertiary period, there cannot be the smallest doubt. They overlie, unconformably, the youngest members of the Cretaceous series, and are interbedded with strata containing a very characteristic Tertiary flora.

The basic rocks of this area described in the present memoir offer a beautiful example of the transition of varieties with a highly crystalline structure, through every intermediate form, into the vitreous type. The holocrystalline forms are true gabbros ("olivine-gabbros" of some authors) which graduate into dolerites, and these in turn pass insensibly into basalt, magma-basalt, and finally into basalt-glass. All these rocks have the same ultimate chemical composition, and, so far as they are crystallized, are made up of the same minerals.

By the study of the microscopic structures of these rocks, it is shown that the passage from the *granitic* type (gabbro) towards the *vitreous* type (tachylyte) takes place along two distinct but parallel lines. Sometimes the gabbro passes into *ophitic* dolerite, and this into basalt and magma-basalt, with skeleton-crystals in the ground-mass. At other times the gabbro passes into *granulitic* dolerite, and thence into basalt and magma-basalts, with granular microliths in their base. The first kind of transition is shown to be characteristic of rock-masses which have cooled down with the most perfect internal equilibrium; the second kind is found in masses which have been subject to internal movements during their consolidation. All the rocks exhibit many interesting varieties of the porphyritic structure, one of which, the "Glomero-porphyritic" structure, has not hitherto been described.

* Quart. Journ. Geol. Soc. vol. xli. (1885) p. 133.

The order of separation of the several minerals in these rocks is shown not to have resulted from purely chemical causes, but to have been controlled by the conditions under which consolidation has taken place. In the most deeply-seated varieties, the iron-oxides enter into complete combination with the silicates, and in other cases there is a progressive increase in the quantity of magnetite which is separated, according to the proximity to the surface at which consolidation has taken place.

Although some of the rocks exhibit a remarkably fresh and unaltered condition in their component minerals, others display the effects of both deep-seated and surface-action in the most instructive manner. There is no essential difference between these altered forms and the similar rocks of pre-Tertiary age. The nature of the changes and the causes by which they have been brought about are shown to vary greatly in different cases, but especial attention is drawn to the deep-seated action to which the name of schillerization has been given, and to the effects produced by the percolation of atmospheric waters.

EXPLANATION OF PLATES IV.-VII.

In the first three Plates an attempt has been made to show the very gradual transition of the most highly crystalline varieties of these rocks into the perfectly vitreous types. Plate IV. is devoted to the illustration of some of the most characteristic and typical varieties of the gabbros, and of their approximation towards the dolerites. Plates V. and VI. illustrate the passage of the dolerites into basalts and magma-basalts. In each of these Plates the figures on the left hand indicate the structure of rocks which have cooled down with the minimum of internal movement and strain (ophitic structures and glass with skeleton-crystals); while the figures on the right illustrate the types in which there has been much internal movement and strain during consolidation (granulitic structure and glass with granular microliths and magnetite dust). It has not been found practicable to give representations of the most largely crystalline types of these rocks, for in such the individual crystals are often more than an inch in diameter; but the series begins with the gabbros of medium-sized grains. These are represented with a very low magnifying power (10 diameters only), and as the crystalline character diminishes, the magnifying power applied to the sections has had to be increased. In drawing the objects it has been found necessary to diminish them to about one third of the size they appear at the position of distinct vision (10 inches), and the enlargement is therefore indicated by the figures $\frac{1}{3}$, $\frac{2}{3}$, $\frac{4}{3}$, &c. The actual size of the objects represented will of course be found by dividing the linear measurements in the figures by the quotients of these several fractions. The least magnified sections are represented within rectangular outlines, the degree of departure from this indicating the progressive increase of the amplification, the most highly magnified sections being represented in circles.

It has not been found necessary to give representations of the porphyritic varieties of all these types, though such exist. Nor did it seem desirable to complicate the question by introducing the more highly altered forms, though these are of considerable interest as illustrating the fact that the degree of alteration is not necessarily a mark of great geological age.

PLATE IV.

GABBROS PASSING INTO DOLERITES.

All the figures on this Plate are magnified $\frac{1}{2}$.

- Fig. 1. Slightly altered gabbro ("olivine-gabbro") of Ardnamurchan. This may serve as an admirable example of the most perfectly holocrystalline type of these rocks, when the minerals exhibit only the incipient stages of change. The felspar is seen in the section forming broad plates with much polysynthetic twinning, and a few irregular cracks and bands of inclusions. The brown augite shows the development of enclosures along lines of strain and fissure, but only the first trace of the foliation characteristic of diallage. The olivine which from its colour would appear to be highly ferriferous, is perfectly clear and free from serpentinization, but exhibits the development of secondary magnetite along the cracks, with the first traces of schillerization along planes parallel to the optic axis of the crystal. There is no original magnetite in the rock.
- Fig. 2. More altered gabbro ("olivine-gabbro") of Loch Coruiskh, Isle of Skye. In this rock the changes due to deep-seated action (schillerization) have gone a little further. The broad plates of felspar, though perfectly clear, contain more liquid and solid enclosures than in the last; the pale brown augite-crystals are, *in their exterior portions*, converted into diallage, by schillerization along planes parallel with the orthopinacoid; the olivine is also more altered than in the last example, and in some cases is rendered completely opaque by secondary magnetite. The augite in the rock is to some extent replaced by a ferriferous enstatite, with bronzite structure partially developed in it.
- Fig. 3. Gabbro passing into eucrite (anorthite-augite rock) from Carlingford Mountain, Co. Down, Ireland. In this rock, the broad plates of felspar are seen to have undergone a considerable amount of deep-seated alteration. The pale-green augite is considerably changed along the lines of strain and fissure. The rock contains but little olivine (none appearing in the drawing), so that, the felspar being anorthite, it approximates to eucrite. There is no original magnetite in the rock.
- Fig. 4. Gabbro, passing into troctolite (anorthite-olivine rock), from the West Glen, St. Kilda, near the junction of the gabbro with the granite. The crystals of felspar are not so large and broad as in the previous examples, and in some cases are seen to be enclosed in the augite, so that there is an approach to the ophitic structure; they are perfectly unweathered, but show traces of schillerization. The augite is small in quantity and in some parts of the rock wholly wanting; it is schillerized on one set of planes and so takes the form of diallage. The olivine is abundant, darkened by secondary magnetite along the cracks, and also forms scattered grains or groups of grains, in the midst of the felspar-crystals.
- [Figs. 3 and 4 illustrate the less normal types of these rocks which result from variations in the proportions of the constituent minerals.]
- Fig. 5. Altered gabbro ("olivine-gabbro") from Mam Clackdig, Isle of Mull. The felspar (labradorite) of this rock is traversed by many bands of cavities containing both liquid and solid materials. The augite is converted, by schillerization, into very typical diallage; the relations of the augite and felspar crystals in some cases indicate an approach-

mation to the *ophitic* structure. The olivine has become almost perfectly black and opaque by the development of magnetite particles in it, and the residual material has been serpentinized.

Fig. 6. More altered gabbro, Loch Coruiskh, Isle of Skye. The felspar is strikingly schillerized, along from one to five planes of the crystal. The augite is schillerized in one set of planes parallel to the orthopinacoid (diallage), or in two sets of intersecting planes, parallel to the orthopinacoid and the clinopinacoid respectively (pseudo-hypersthene). The olivine, which is small in quantity, is converted into serpentine often penetrating into the cracks of surrounding minerals. The relations of the augite and felspar-crystals suggest, as in the last example, an approach to the *ophitic* structure.

[Figs. 5 and 6 illustrate the more advanced conditions of alteration in these rocks, by which they are made to resemble in their character the gabbros (olivine-gabbros) of the older geological periods.]

Fig. 7. Gabbro passing into dolerite, from Ardnamurchan. In this rock the felspar, which is unweathered, but contains many inclusions, no longer forms the large and broad crystals characteristic of the true gabbros, but begins to assume long prismatic forms. The pale brown augite, which is schillerized, and passes into diallage along the outer margins of its crystals, shows a decided approach to the *ophitic* arrangement in its relations to the felspars. The olivine forms irregular grains, which exhibit various stages of the development of secondary magnetite in them.

Fig. 8. Gabbro passing into dolerite, from near the summit of Halival, Isle of Rum. In this very beautiful and almost wholly unaltered rock the breaking up of the broad crystals of felspar into "lath-shaped" forms is carried still further. The rich green augite (diopside) forms rounded grains, but these sometimes enclose lath-shaped felspar crystals. The olivine, which also occurs in rounded grains, is very fresh, but contains the stellar groups due to schillerization; by slight alteration along the cracks it has assumed a yellow-brown tint, as seen in the fractured surface of the rock (see pp. 67, 68).

From examples like those represented in figs. 7 and 8, we find the most insensible transition to the true dolerite figured in Plate V.

PLATE V.

DOLERITES PASSING INTO BASALTS.

This Plate represents the structures of the dolerites and basalts and of the rocks which constitute the transition between these two varieties.

Figs. 1 to 4 are shown as magnified $\frac{2}{3}$, and Figs. 5 to 8 are shown as magnified $\frac{1}{3}$.

In this and the following Plate the rocks which have been formed by the consolidation of materials in a state of internal equilibrium, are represented in the column on the *left* hand, and those in which movement has taken place during consolidation, on the *right*.

Fig. 1. *Ophitic* structure in dolerite from the Shiant Isles. The section shows dark purplish-brown augite, enclosing more or less lath-shaped crystals of felspar, both minerals being beautifully fresh and unaltered. A few scattered grains of olivine, slightly serpentinized along the cracks, occur in the rock, with patches of magnetite; and both of these minerals sometimes enclose the felspars in the same way as does the augite. Where weathering action has affected the augite, it has acquired the peculiar colour and pleochroism, but none of the other characters of hornblende (see pp. 68, 85).

Fig. 2. Granulitic structure in dolerite from Ardnamurchan. In this section we find an interwoven network of lath-shaped felspar crystals, through which irregular grains of pyroxene, olivine, and magnetite are scattered, these grains being distinguished by their rounded contours and

the diversity of their orientation, as is shown when they are examined by the aid of the polariscope. Some of the magnetite is probably original, but a considerable part of it is clearly secondary, and formed by the alteration of the olivine. The augite in places shows the commencement of schillerization, and tends to pass into diallage. Portions of this rock become porphyritic by the addition of large, zoned crystals of felspar (see p. 68).

- Fig. 3. Semi-ophitic structure in basalt from Portree, Isle of Skye. This is a good example of a type very characteristic of the coarser-grained basalts of the district. The amount of unindividualized glass is very small, so that the rock is almost a dolerite, according to the definition which we have adopted. The lath-shaped felspars are narrower and less clearly defined in outline than in Fig. 1. The augite, though usually behaving in the *ophitic* manner, sometimes breaks up and becomes *granulitic*; and this is more conspicuously the case with the olivine and magnetite. The rock contains large porphyritic crystals of olivine. This type, so common among the coarser basalts of the Western Isles of Scotland and the North of Ireland, is admirably represented in Iceland (see R. Bréon's 'Iceland,' plate ii. fig. 2).
- Fig. 4. Semi granulitic structure in basalt from Ru Geur, Isle of Skye. This rock, like the last, contains only a trace of a vitreous ground-mass, and may, like it, be regarded as one of the links between the dolerites and the basalts. The felspar forms narrow and often ill-defined lath-shaped crystals; the augite is usually granular, but in places shows an approximation to the *ophitic* type, the orientation of adjacent grains which enclose the felspar crystals being not unfrequently the same. The rock contains porphyritic crystals of both olivine and felspar. This type, like the last, is very frequently represented among the coarse-grained basalts forming the more massive lava-currents of the district. The two types pass into one another by insensible gradations.
- Fig. 5. Micro-ophitic structure in the basalt of Dumfryn, near Tobermory, Isle of Mull. In the section of this lava we find the brown augite developed around the small lath-shaped microlites of felspar so as to produce a very perfect ophitic structure on a very minute scale (compare with fig. 1, bearing in mind that fig. 5 is magnified three times as much as fig. 1). The rock contains grains of olivine, which is converted into serpentine, and is rendered porphyritic by large crystals of plagioclase felspar. There is a small quantity of glassy ground-mass in the rock. So far as my experience goes, this micro-ophitic structure is only of rare occurrence.
- Fig. 6. Micro-granulitic structure in a basalt from Ardnamurchan. In this rock the granulitic structure is exhibited on a very minute scale (compare with figure 2, bearing in mind the difference of amplification). In a plexus of short felspar crystals we find scattered rounded grains of pyroxene and olivine, the diverse orientation of these grains appearing very distinctly when the section is viewed by polarized light. The rock is not porphyritic, and the particular type of structure appears to be somewhat rare.
- Fig. 7. Structure seen in basaltic dyke in the Isle of Scalpa, near Skye. The felspar and augite appear as somewhat ill-defined microlites, the latter exhibiting a fibrous appearance. The whole of the rather abundant glassy base is filled with rods and skeleton-crystals of magnetite, which sometimes start from the sides of the augite microlites. The imperfect crystallization of the several minerals is very well seen when the section is examined by polarized light.
- Fig. 8. Structure seen in the basalt of a lava-current exposed at the western foot of Beinn Inivaig, Isle of Skye. In this section we have the granulitic structure well exemplified, but the granular microlites of augite are smaller and less perfectly defined than in figs. 4 and 6; and the surrounding plexus of felspar-microlites is less distinctly individualized, the quantity of glass in the ground-mass being much

greater. The magnetite forms large irregular grains. This type admirably illustrates the transition between the porphyro-granulitic dolerites and the most common type of basalts forming the lava-streams of the district, in which minute granules of augite and olivine with ill-defined lath-shaped microlites of feldspar are scattered through a vitreous base. See Plate VI. fig. 2.

PLATE VI.

BASALTS PASSING INTO MAGMA-BASALTS.

The first four figures on this Plate are shown as seen with a magnifying power of 150 diameters ($\frac{1}{3}\alpha$), the remaining four with a magnifying power of 300 diameters ($\frac{2}{3}\alpha$).

- Fig. 1. Compact basalt from a dyke at Carsaig, Isle of Mull. The glassy base is filled with beautiful rods and skeleton-crystals of magnetite; irregular and ill-defined microlites of feldspar are seen more or less enclosed (in the ophitic manner) in the also somewhat ill-defined augite-microlites. The scattered grains of olivine are completely serpentinized. This section illustrates the combination of an imperfect ophitic structure with one in which skeleton-crystals are conspicuous, both types characterizing the basalts which have consolidated with perfect internal equilibrium.
- Fig. 2. Compact basalt of the Giant's Causeway, Co. Antrim, Ireland. Irregular lath-shaped microlites of feldspar with granular microlites of augite and olivine are set in a small quantity of a glassy base, filled with granular particles of magnetite, and similar granules and globulites of magnetite are sometimes found enclosed in the augite- and feldspar-microlites. This rock illustrates the common type of the more compact basalts of the area.
- Fig. 3. Compact basalt from near Tobermory, Isle of Mull. In this rock such a large quantity of glassy base is present that it might perhaps almost be considered as a magma-basalt. Through the glassy base are scattered needles of feldspar and augite, the latter sometimes aggregated into fibrous and plumose masses, which enclose the former with very minute black rods and granules of magnetite. The structure exhibited is very similar to that of some of the "light magma-basalts" of Bořický.
- Fig. 4. Compact basalt from Lismagogue, Co. Antrim, Ireland. This variety differs from that of fig. 2, chiefly in the larger quantity of glassy base thickly set with granules of magnetite. The same irregular microlites of feldspar, with the rounded granules of augite, are found in this rock, as is so commonly the case with the basalts of lava-streams. The olivine which is small in quantity, is completely serpentinized. The rock approaches in its characters the "dark magma-basalts" of Bořický.
- Fig. 5. Magma-basalt from a dyke at the Beal, near Portree, Isle of Skye. The structure of this rock resembles that of fig. 3, but the crystallization of the several mineral constituents has not gone so far. Rods of magnetite and irregular lath-shaped microlites of feldspar are scattered through the mass. The enclosing glass is filled with minute crystallites of augite which are only very occasionally seen to be united into the fibrous and plumose masses found in fig. 3. The glass crowded with the augite, crystallites encloses the feldspar microlites in the same way that the augite does in the ophitic dyke of rocks. It is clear that fig. 5 represents a type of rock in which a larger part of the material remains in a vitreous condition than that represented in fig. 3, and one in which the crystallization of the minerals, especially of the augite, has not gone so far.
- Fig. 6. Magma-basalt from near Tobermory, Isle of Mull. This rock resembles the common type represented in figs. 2 and 4 except for the fact that the bulk of the material remains in the glassy condition. The

felspar is represented by very ill-defined lath-shaped microlites, and the augite by granular particles of which the outline is also ill-defined, with others in which the polarization is very obscure—in fact they should be called crystallites rather than microlites; more or less rounded grains of magnetite, with “magnetite-dust” and magnetite globulites, are also scattered through the glass.

Fig. 7. Magma-basalt from a dyke at Gribun, Isle of Mull. This differs from fig. 5 in the absence of any distinct crystalline forms. In the mass of glass the feldspars are probably represented by crystallites in the form of long rods often bifurcating at the ends, and it is doubtful if any other mineral except magnetite has begun to separate from the glass. The magnetite forms an intricate network of rods and skeleton-crystals, which are sometimes seen to spring from the sides of the embryo-crystals (crystallites) of felspar.

Fig. 8. Magma-basalt from a lava-stream at Bloodstone Hill, Isle of Rum. Through the abundant pale brownish glass of this rock we find scattered groups of short crystallites (belonites) of felspar, granular crystallites of augite, and grains of magnetite, these embryo-crystals being usually collected into groups. The contrast between the rocks represented in figs. 7 and 8 is very striking, and is evidently the result of differences of condition during the consolidation of the two rocks.

[The completely vitreous basalt-glass or tachylyte has already been sufficiently illustrated (see *Quart. Journ. Geol. Soc.* vol. xxxix. pl. xiv. figs. 1, 2, 3, 4, 5). In these the sections are represented as seen with a still higher power (500 diameters) than we have employed for the magma-basalts. These tachylytes are from the edges of the dykes, and in all of them except fig. 1, rods and skeleton-crystals of magnetite are thickly scattered through the glassy base. Sometimes these rods are seen to be lines of globulites (“margarites” of Vogelsang). The cloudy granular condition of the magnetite in fig. 1 may be the result of a certain amount of friction between the cooling glass and the walls of the dyke.]

PLATE VII.

- Fig. 1.** Crystal of felspar from the porphyritic gabbro of Ardnamurchan. Natural size. The porphyritic crystals of felspar in this rock are from 1 to 2 inches in length. In the example figured, it is seen that the crystal, subsequently to its formation, has yielded to mechanical forces, cracks being formed, generally along cleavage-planes, but sometimes passing irregularly through the crystal. These cracks have been injected with material which has become perfectly crystallized as augite. The whole crystal with its enclosures has undergone some alteration, numerous fissures and enclosures being produced in the felspar substance, while the augite has in places been darkened by the separation of magnetite.
- Fig. 2.** Porphyritic crystal of felspar in the granulitic dolerite of Ru Geur. Magnified 75 diameters. This crystal, besides being very much broken or eroded along its edges, has yielded along the planes of most easy cleavage, and permitted the infiltration of augitic material, which has crystallized. The contrast between this infiltrated augitic material and the granulated augite in the base of the rock is very marked. Both this and the last figure afford striking illustrations of the tendency of the felspar in these rocks to crystallize before the augite.
- Fig. 3.** Glomero-porphyritic structure in the dolerite of Fair Head, Co. Antrim, Ireland. Magnified $2\frac{1}{2}$ diameters. The ground-mass of this rock is an ophitic mass, consisting of brown augite and dark-coloured olivine, both enclosing lath-shaped crystals of felspar in great profusion. Scattered through this base, we find aggregates of crystals of olivine and anorthite; in these aggregates the grains of olivine are generally enclosed by a mass of the broad anorthite crystals, so that the relations of these two minerals is the same as is seen in troctolite

("Forellenstein"); the rock, indeed, appears like an ophitic dolerite through which portions of a troctolite are scattered, though, as pointed out in the text (p. 71), this may not be the real explanation of the origin of the structure.

Fig. 4. Augite crystal from the gabbro passing into dolerite seen on the south side of the West Glen, St. Kilda. Magnified 180 diameters. The central part of this crystal presents the ordinary characters of augite, the whole extinguishing together; but along its edges the augite becomes "granulated" or broken up into masses of granular particles, each of which has a different orientation. This structure may have been produced by crystallization having gone on to a certain extent, while the mass was in a state of perfect internal equilibrium, but, before final consolidation, some internal movement or strain having been set up within it (see p. 76).

Fig. 5. Zoned crystal of augite from the piperno of Pianura near Naples. Magnified 100 diameters. The central portion of this crystal is of a pale green colour and exhibits the characteristic cleavage-cracks of augite; it is quite destitute of pleochroism. The outer zone, which is not sharply divided from the central mass, but appears to graduate insensibly into it, is of a rich yellowish-brown tint, and exhibits the characteristic pleochroism of a moderately ferriferous enstatite (proto-bronzite), reddish brown to bluish green. The outer surface of the crystal, where it is in contact with the surrounding magma, exhibits the irregular black band so often seen in hornblende and mica-crystals under similar circumstances. Although the outer zone of this crystal is so strikingly distinguished from the central part by its strong pleochroism, yet, so far as I can make out, they extinguish together; some of the cleavage-cracks of the central mass also seem to pass without change into the outer zone. Owing to the narrowness of this outer zone, I have not found it practicable to compare the interference-figures given by the two portions of the crystal with convergent polarized light. This example is very instructive when compared with the augite of the ophitic dolerite of the Shiant Isles (see Plate V. fig. 1). In this we sometimes find the purplish-brown non-pleochroic augite shading into a material of a yellowish-brown tint, exhibiting in a very marked manner the characteristic pleochroism of hornblende; this pleochroic portion of the augite crystals still exhibits the characteristic cleavage and the extinction-angle of the augite. These examples seem to indicate that in the paramorphic changes of augite into hornblende and enstatite respectively, the peculiar pleochroism of the paramorphic minerals is the first character which is acquired (see p. 65, footnote).

Fig. 6. Altered augite from the gabbro (olivine gabbro) Isle of Mull. Magnified 25 diameters. This example is very interesting on two grounds. In the first place, we have twinned crystals like those occurring commonly in the Whin Sill and so well described by Mr. Teall (Quart. Journ. Geol. Soc. vol. xl. (1884), p. 647 &c., pl. xxix.). Such twinned augites do not appear to be at all common in the rocks of the district we are describing. The crystals have been perfectly schillerized and have assumed the foliation of diallage. In the second place, it is noteworthy that though the augite material has been converted into "viridite" substance, or, in other words, the crystals are undergoing uralitization, yet the enclosures still remain which were formed during the secondary foliation of the mineral. These enclosures appear to have contained so much titano-ferrite that, by weathering action, they have yielded the characteristic white product known as "leucoxene," giving a very peculiar appearance to the altered product (see p. 85).

Fig. 7. Two grains of serpentinized olivine in a gabbro (olivine-gabbro) from Portsoy, Scotland. Magnified 30 diameters. The expansion of the olivine during its hydration is seen to have produced series of radiating cracks traversing the surrounding crystals of felspar and augite, and these cracks have been injected with the serpentinous matter. The

effects of this action are especially well seen in the augite crystal, which, by schillerization, is partially converted into diallage. These radiating series of cracks proceeding from the olivine grains, and injected with serpentine, are generally very well seen in the troctolites ("Forellensteine") among the older rocks, where the olivines are more or less perfectly serpentinized (see p. 86). In the Tertiary rocks it can frequently be recognized, and in some of the more altered gabbros, like those of Mull and Skye, all the minerals of the rocks have their cracks thus injected with serpentine.

Fig. 8. Micropegmatitic (?) structure in the plagioclase felspar of the altered gabbro of the Isle of Mull, seen as magnified 30 diameters. Compare this with the admirable figure given in R. Bréon's 'Géologie de l'Islande,' plate vi. fig. 2. The manner in which this structure is seen to be developed in the outer zones of some felspar crystals, and especially in those which fill up the interspaces between other earlier-formed and well-defined crystals, and the way in which they are constantly associated with undoubtedly secondary quartz, all point to the conclusion that this structure is not an original, but a *secondary* one (see page 72). As an illustration of the commencement of these secondary structures in felspars the next drawing, fig. 9, is given. In the group of crystals represented in fig. 8 we find several plagioclase crystals, one of which encloses a granule of garnet, while the outer zone of another exhibits the "micropegmatitic" structure. The same structure is seen in the surrounding crystals. The clear material appears to be quartz. The cloudy matter between may be kaolin (?). Infiltrated serpentinous matter, with clear secondary quartz and a crystal of augite schillerized and converted into diallage on its outer margin, is seen in the same group.

Fig. 9. Incipient stage of a secondary structure seen to be developed in the felspars of a gabbro, from Portsoy, Scotland, magnified 180 diameters. (A similar structure has, on more than one occasion, been mistaken for the canal-system of *Eozoön*!) Certain isolated portions of the felspar crystals appear to be attacked in this way, and every stage of the process may be studied in different specimens, from the incipient appearance represented in the figure to a structure closely resembling the so-called micropegmatitic shown in fig. 8. I have not been able to determine the mineral substance which forms these radiating and plumose masses which penetrate certain portions of the twinned felspar (see page 73).

DISCUSSION.

The CHAIRMAN congratulated the author on his paper, and said that he had no doubt the evidence of the fossil plants from the associated leaf-beds would prove the rocks referred to to be of Older Tertiary date. Mr. J. Starkie Gardner had procured very extensive series of these remains, and was now engaged in working them out.

Mr. RUTLEY was very glad to find that the author objected so strongly to the attempt at classifying igneous rocks according to age. He thought that the term "diabase" might be dropped. The structures represented in the diagrams were quite familiar; but the terms "granitic," "ophitic," &c., might perhaps with advantage be replaced by "coarse-grained," "medium-grained," and "fine-grained," the differences existing only in structure and not in constitution. He alluded also to the different phases of "micro-crystalline" structure. A most interesting point was the distinction between coarse-grained deep-seated rocks, less coarsely crystalline, and, finally, vitreous conditions of basalt, near the surface; in this

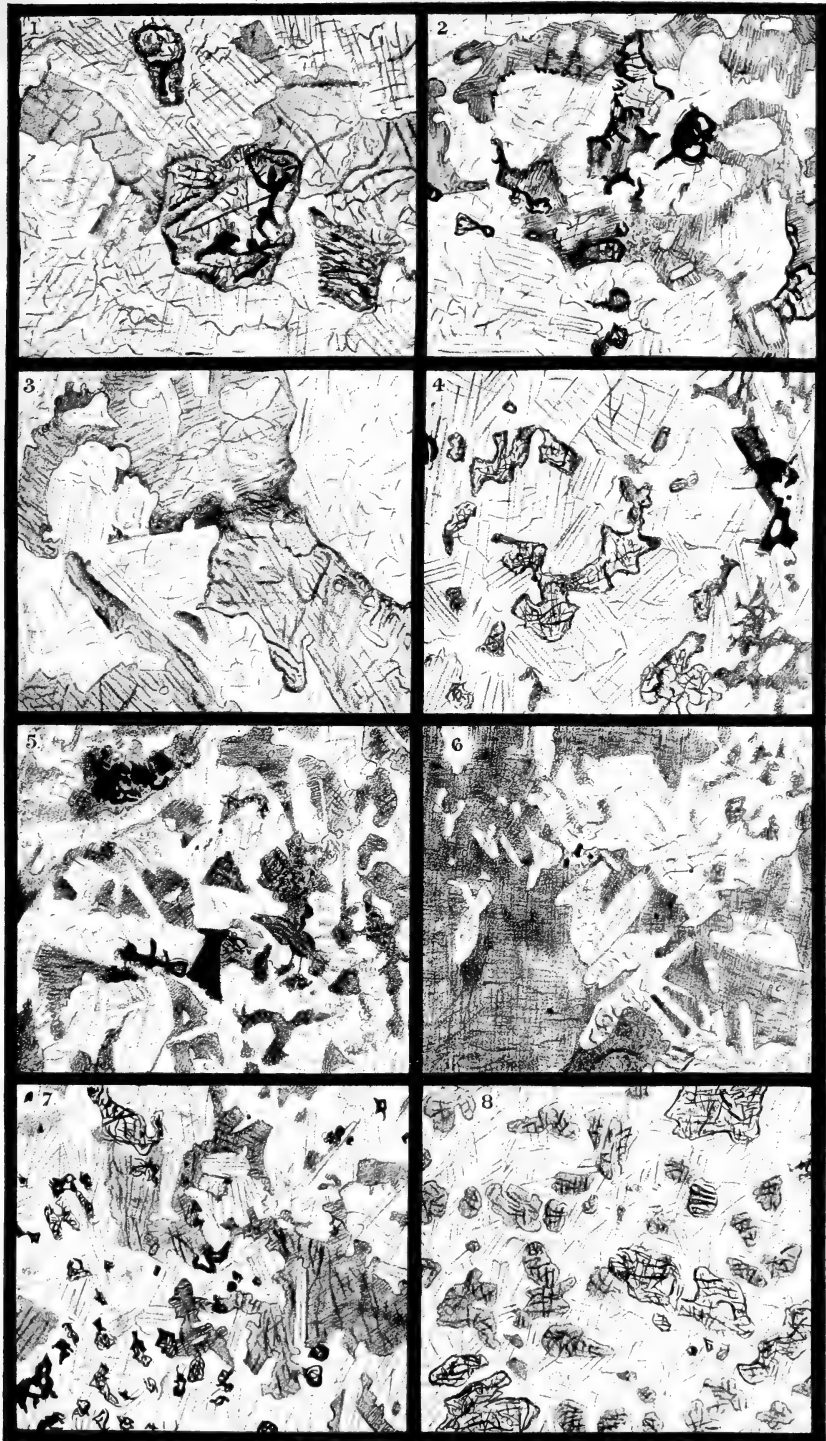
he thoroughly agreed. He cordially endorsed the high opinion expressed by the author of the work done by Messrs. Hague and Iddings upon Transatlantic rocks. He remarked that lavas of totally distinct characters are poured out from the same vent, so that the use of the term "petrographic province" seemed to be of rather doubtful propriety. Glomero-porphyritic structure, he thought, might perhaps be due to the breaking up of crystals, as occasionally seen in glassy rocks. The cavernous structure of some crystals was probably not due to corrosive action in the rocks. Palagonite had been discussed some years ago, and its nature appeared to be doubtful. Felspar crystals were apparently not always the minerals first formed in rocks of a doleritic or andesitic type.

Mr. J. STARKIE GARDNER said that he had been working for some four or five years upon the question of the age of the leaf-beds associated with the basalts in Ireland and the Western Islands of Scotland. The conclusion at which he was arriving was that they extended from pre-Eocene (although not Cretaceous) to Middle Eocene times.

Prof. BOYD DAWKINS remarked that the microscopical study of rocks seemed to have led to much the same conclusions as the earlier and rougher modes of macroscopic investigation. The relations of structure to heat and pressure in presence of water had been made out before the more delicate methods of modern petrological research had revealed the minuter details. The old classification of the rocks in its main outlines still holds good.

Mr. TEALL said that all petrographers would thank Prof. Judd for his detailed descriptions of the Tertiary igneous rocks of the west of Scotland. The hesitation which many workers had shown in accepting his views was probably due in a great measure to the absence of detailed petrographical descriptions. He agreed with the author that there was a distribution of igneous rocks in space and time which could only be described in a satisfactory manner when a classification based solely on the chemical, mineralogical, and physical characters of rocks was established. The introduction of geological age as a primary factor in classification obscured natural relationships, implied differences which did not exist, and rendered impossible the accurate description of the distribution in time of many important rock-types. In limited areas there were differences which could be definitely connected with geological age. The ophitic texture, for instance, was especially characteristic of the pre-Tertiary basic igneous rocks of Germany; and absent, so far as the speaker was aware, from the corresponding rocks of Tertiary age in the same area. It would be a mistake, however, to regard this texture as a special characteristic of pre-Tertiary rocks all the world over, or as of the smallest use in fixing the age of a rock from any new locality; for it was now known to be a special feature of the dolerites of the north of Ireland, the west of Scotland, and Iceland.

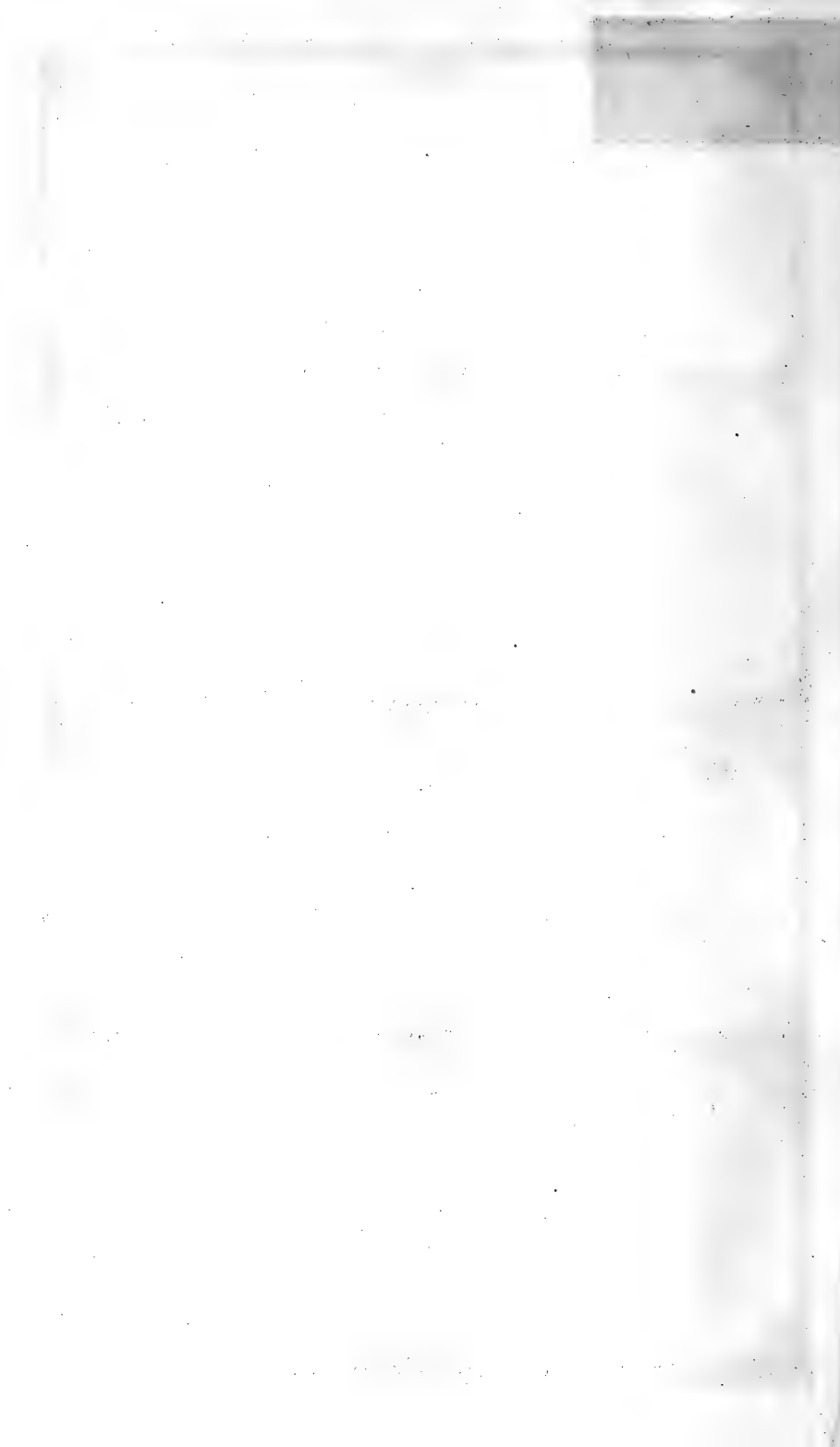
The AUTHOR, in reply, said that the term "gabbro" has been so extensively employed that it cannot well be dropped. Mr. Rutley,

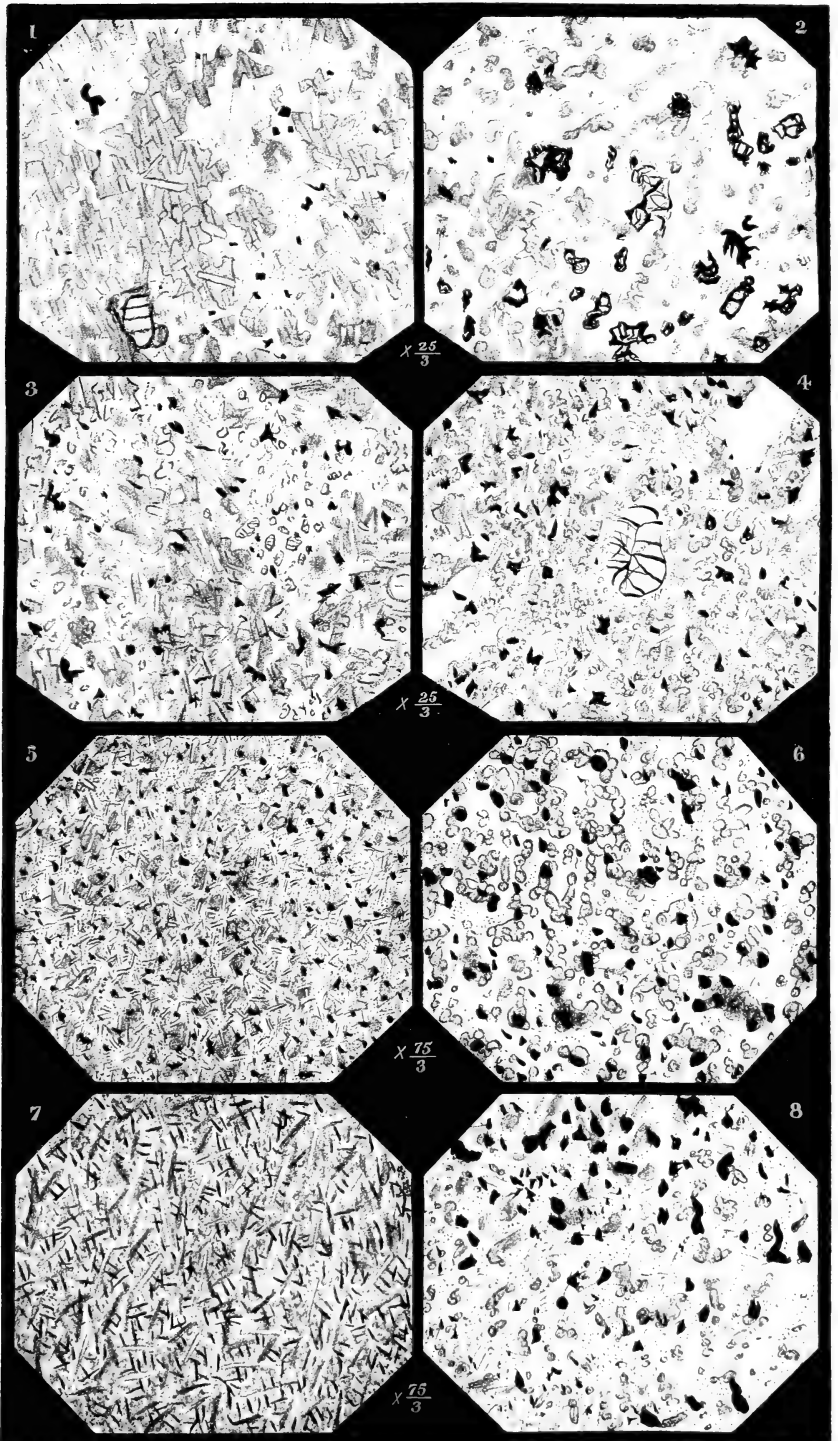


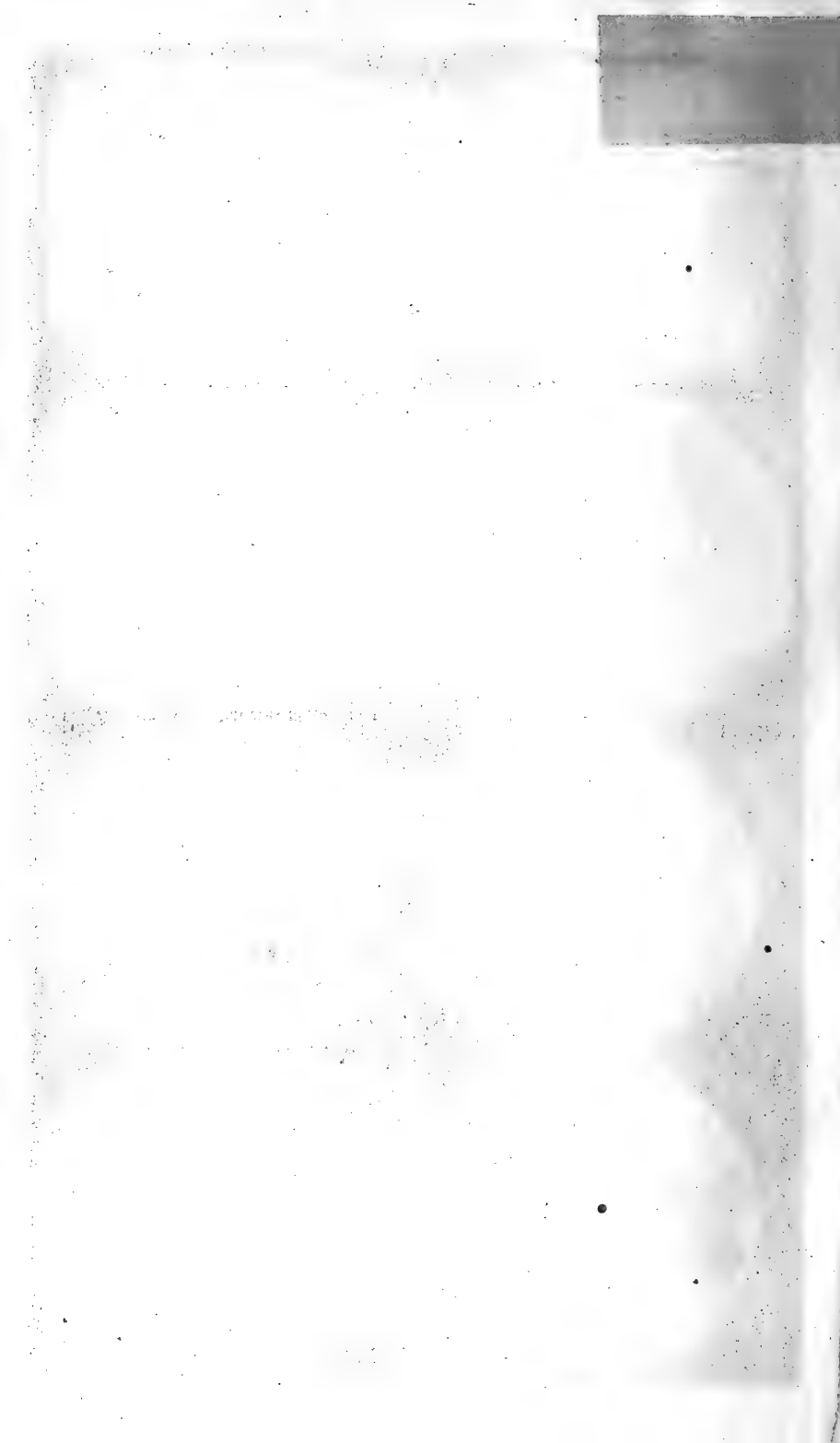
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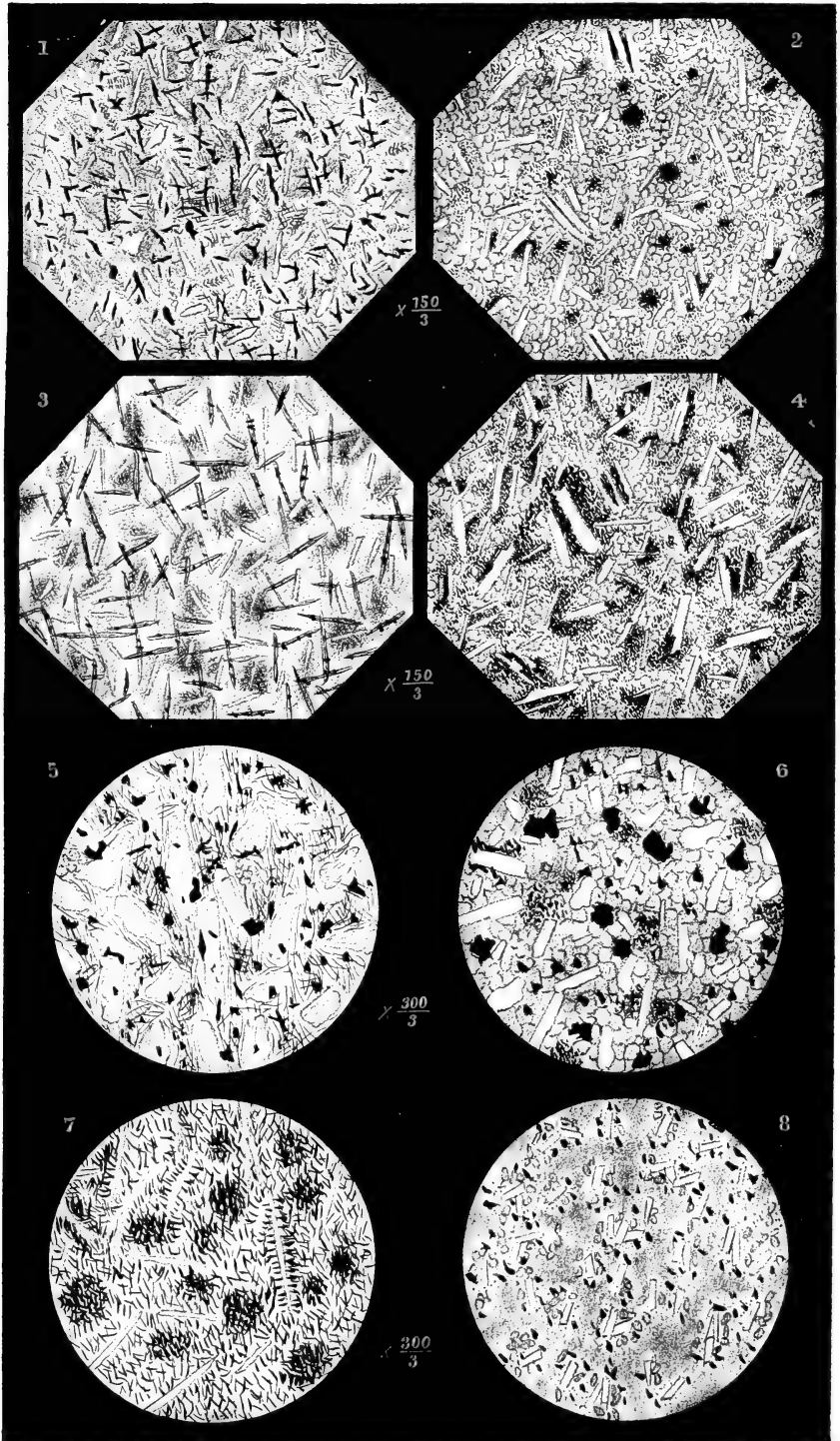
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GABBROS PASSING INTO DOLERITES. ($\times \frac{10}{3}$)



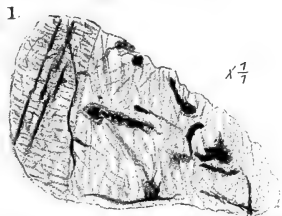






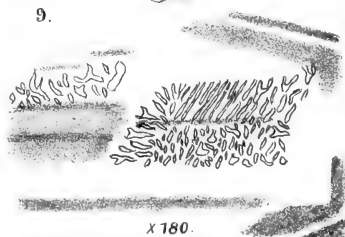
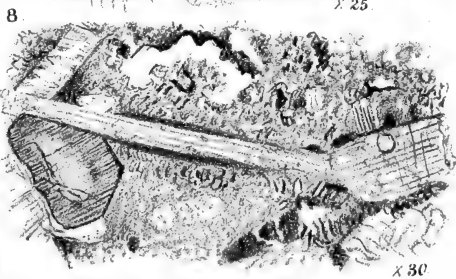
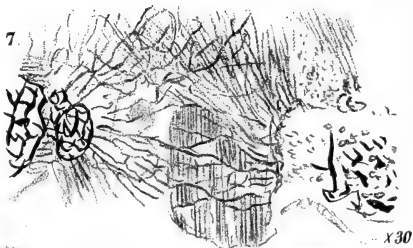
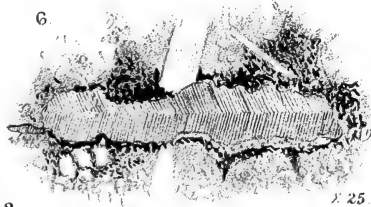
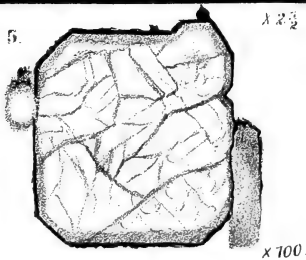
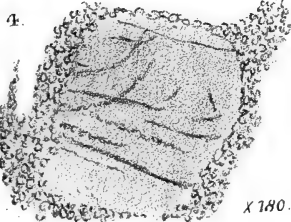
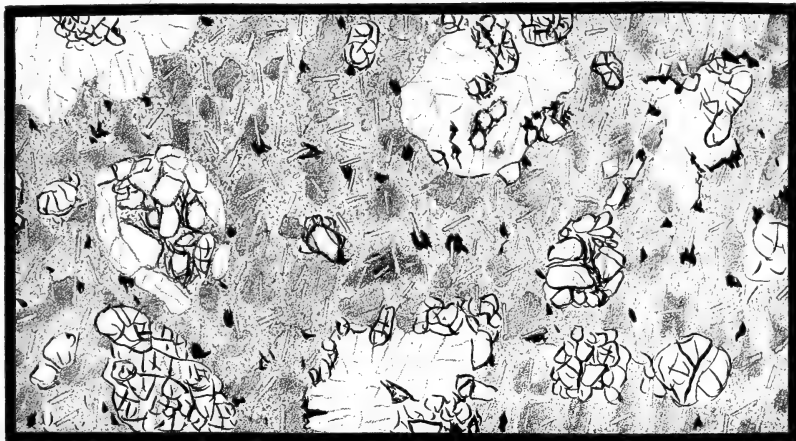
BASALTS PASSING INTO MAGMA-BASALTS.





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he thought, had not quite understood the question of petrographical provinces. Both acid and basic rocks occur in each, as he showed from instances in Hungary and Bohemia. Glomero-porphyrific structure might or might not be due to the breaking up of an earlier-formed troctolite. Palagonite was certainly not a mineral, but a hydrated glass. The final results of Mr. J. S. Gardner's work would be very welcome; the important point at present is that all the rocks are later than Cretaceous. He agreed with Mr. Teall that there is a distribution of rocks both in space and time.

7. OLD SEA-BEACHES at TEIGNMOUTH, DEVON. By G. WAREING ORMEROD, Esq., M.A., F.G.S. (Read December 16, 1885.)

TEIGNMOUTH, consisting of East and West Teignmouth, is built partly on the outcrop of the Triassic beds, and partly on a sandy level that lies between them and the sea. The Trias can be traced from near East Teignmouth Church, along the railway-cuttings, by Orchard Gardens, to the bank of the Teign at the Old Quay. A level gravelly district forms a triangle from near East Teignmouth Church to the "Point" at the estuary of the Teign, thence to the Old Quay, and thence to East Teignmouth Church. In carrying out a scheme of drainage in 1885, the cuttings showed that at least two series of beaches exist; and documentary and other evidence prove that, except as to the surface, no change has taken place in recent times. In 1044 Edward the Confessor granted Dawlish, which included East Teignmouth, to his chaplain Leofrick. The part referred to in this paper reached from the Point to the estuary, by the coast of the harbour to the mouth of a rivulet called the Tame, then known as "Crampan steoart," but now as "Gale's Hill"; the boundary then followed the stream by the "Salterns," showing that the sea then ebbed and flowed in that stream as it does now, occasionally, at spring-tides, rising up into the streets, and also that the stream of the Teign then passed on the south side of the valley. After passing the "Salterns," the boundary left the rivulet and crossed to the west of the church east of Teignmouth. (See Davidson, *Trans. Devon. Assoc.* 1881, p. 113.) The Salterns, which were situated in the Strand, were demolished in 1692, but their remains were visible many years after (MS. of the late Mr. R. Jordan, quoted by Dr. Lake, *Trans. Devon. Assoc.* 1874, p. 376). From a view of Teignmouth on a map of Ringmore dated 1741, it would appear that many houses then existed along the south side of Teignmouth; it may therefore be inferred that no perceptible change of level has here taken place except that caused by the formation of streets. As regards the north-eastern part, the case is different: about fifty years ago a great part of the surface consisted of a sandy swamp intersected by pools of water; there were not many dwellings; one place was called Rat Island, another was known as Frog-marsh Hill. About the year 1872 it was needful to pull down two houses at the north-eastern end of the Triangle; it was then found that the party-wall was built over a very old granite cross; the shaft formed part of a chimney jamb, the base rested on fine sand, about three feet below the surface, or on the level of high water at spring-tides. This cross was unknown, and was probably the old "Market Cross" of East Teignmouth.

The cutting for the sewer commences, at low water, at Gale's Hill and is carried in nearly a north-easterly direction to the sea-wall, crossing Somerset Place, along Brunswick Street, at the back of the Club, at the Queen's Hotel, along the east side of the Triangle, and along Regent Street. A branch passes along Somerset Place and Fore Street, with branches at Bank Street and Orchard Gardens;

and a sewer is carried along Wellington Street to Regent Place ; these are the chief places that will be noticed. Spring-tides rise 13 feet above low water.

In Somerset Place the surface is 15 feet above sea-level at low water ; the cutting was 9 feet deep, and many shells, mostly much worn, occurred at the bottom in dark loamy sand ; these were overlain by brown sandy gravel 2 feet, light brown sand 18 inches, brown sandy gravel with small stones at the top 2 feet, and above clay and earth ; a similar deposit was found at the south-western end of Bank Street. The shells found were *Buccinum undatum*, *Turritella terebra*, *Nassa reticulata*, *Purpura lapillus*, *Patella vulgata*, *Ostrea edulis*, the same with Barnacles, *Solen siliqua*, *Macra stultorum*, *Cardium tuberculatum*, *C. edule*, *Scrobicularia piperata*. This deposit is apparently confined to the south-west of the Tame rivulet. I had not an opportunity of seeing where this deposit ceases and the following gravels begin ; but the distance is very short. A few shells were found in the sand at the depth of 7 feet at the junction of Brunswick Street and Carlton Place ; but the well of the Club, a few yards to the east of this place, passes through 15 feet of fine gravel without shells. The cuttings in Den Street and at the back of the Queen's Hotel are through sand without shells ; but at the southern angle of the Triangle a few bivalves occurred in sand at the depth of 8 feet. At the meeting of Den Street, Orchard Gardens, and Bank Street the cutting was through 7 feet of gravel without shells. In Wellington Street, the continuation of Bank Street, a few shells were found, and a little further to the north-east they were found in Triangle Place, and thence through Regent Street to the sea-wall. The following shells were found in these cuttings :—*Littorina litorea*, *Patella vulgata*, *Macra stultorum*, *Scrobicularia piperata*, *Lutraria elliptica*, *Ostrea edulis* (one of these shells contained a pearl), *Cardium edule*, *Mytilus edulis*. The *Littorina litorea* was only found in two places.

The line of cutting shows three deposits of sand and gravel. The first extends from the mouth of the Tame nearly, if not quite, to the Trias in Orchard Gardens, and consists of a bed of rolled shells in compact loamy sand overlain by beds of sand and gravel ; the second is of fine sand like sea-sand, and reaches to the Triangle ; the third extends to the sea-wall, and contains shells which, with one exception, are delicate bivalves ; these occur near the bottom of the cutting, and the sand did not appear to be divided into beds or layers.

The recent superficial changes will be noticed hereafter. A deposit of fine sand similar to that cut through in Den Street seems to have covered most of the district here mentioned, except Somerset Place ; it occurs in the Triangle-cuttings, at the Club, in the foundations of the Baths and Market, and elsewhere. It is probable that the deposit in Somerset Place, which must have been gradually formed, was part of the oldest sea-board with which we are here acquainted, and that this had been partly carried away by some storm in days long ago ; that the light sands in the Triangle, with shells, were deposited at a later date ; and these shells are so very perfect and tender that this must have taken place in a calm sea.

This deposit was, in its turn, partly washed away, and sand without shells deposited in hollows, as at Den Street, and over the denuded beds at the Triangle and the other gravels. Any of these changes are such as would be made by a strong equinoctial gale at the present day, if the shore was not protected by sea-walls. Even now the railway-wall was thrown down not long ago. The Den is protected by sea-walls; but these are occasionally, as in March 1884, broken down by a storm, and the "Point" is, from time to time, swept away, but is soon renewed. In former days grass was planted to preserve the sand, and the parishes in the hundreds of Exminster and Teignbridge were obliged to keep up the "Bulwarks of East Teignmouth." (Dr. Lake, *Trans. Devon. Assoc.* 1874, p. 378.) With respect to the present surface in the north-east, as before mentioned, the base of an old granite cross, similar to most of those on Dartmoor, showed that when it was erected the level of the ground was about 13 feet above low water, or about the height of spring-tides; judging from excavations that have been made, such must have been the general level of the district. The marsh was caused principally by the water of the Tame being backed up; as, except in heavy storms with an easterly wind, the sea does not break over the sea-wall, which rises from 21 to 24 feet above low water. In consequence of building and the drift sand the surface has been gradually raised about three feet in later days; but it rarely happens that any remains are found. I believe that the only article found during the recent cuttings was a wooden post, 5 feet long and 10 inches in girth, which was discovered in Holland Road, 7 feet below the surface. An iron halberd, probably of the sixteenth century, was found in gravel two or three feet below the surface during the excavations for the New Baths; a description of this is given by myself in the *Transactions of the Devon Association*, 1883, p. 141.

For the determination of the shells, I am indebted to my sister, Miss G. E. Ormerod; for the levels, to the map in "The Report on the Drainage of Teignmouth" by Dr. Lake, 1872; for the depths of the cuttings, to Mr. G. Crow, Surveyor to the Teignmouth Local Board.

DISCUSSION.

Mr. CHAMPERNOWNE pointed out that the author's conclusions agreed with those of Mr. Pidgeon, drawn from observations in a neighbouring locality, inasmuch as they tended to show that but little change of level had occurred since early historical times. Evidently the beaches mentioned by the author were newer than the raised beaches.

Prof. BOYD DAWKINS remarked that there was similar evidence from other quarters as to the permanence of our sea-margins since Roman times. The sea-level is proved by the position of the Roman harbours, as, for example, at Pevensy, to have been the same on our southern coast as it now is. The evidence of depression on the opposite side of the Channel, and in the Channel Islands in modern times, based on submerged forests and legends, is unsatisfactory.

8. *On the ASTROCCENIÆ of the SUTTON STONE and other Deposits of the INFRA-LIAS of SOUTH WALES.* By Prof. P. MARTIN DUNCAN, M.B. (Lond.), F.R.S., F.G.S. (Read November 4, 1885.)

[PLATE VIII.]

A VERY well-preserved specimen of *Astrocœnia gibbosa*, nobis *, has lately come to hand which was collected by the late E. B. Tawney, Esq., F.G.S., and as it illustrates many interesting points in regard to the morphology of the species, I have thought that a description of it would be interesting to those Fellows of the Society who take an interest in the Madreporaria of the Jurassic strata.

The specimen is gibbous and worn on the free surface, and it has been carefully cut transversely and polished at the distance of an inch from the top. The form has grown vigorously in some parts and more slowly in others, and there are quite young as well as old corallites to be observed in the colony. Except in one or two places, fossilization has not interfered with the perfect preservation of the structural details, and the originally hard parts of the coral are represented by dense white mineral, while the interspaces are filled with more or less transparent, dark, carbonate of lime.

On one side of the specimen and on the upper surface close by, are some corallites, which, as they are characteristically Astroccœnian, may be noticed first of all. On the side of the colony the corallites have been worn so as to show longitudinal views of their walls and septa (Pl. VIII. fig. 1). The walls of adjacent corallites are united, and it is only in one or two places that a very thin line of semi-transparent calcite denotes that the fusion has been incomplete. Elsewhere the walls of the corallites are perfectly united, the line of junction being invisible. The width of the joined walls is small, and it varies at different heights in the exposed portions; sometimes the combined structure is as broad as one half, and in most places it is about one fifth of the diameter of a calice. These measurements give the presumed width of the wall of each corallite as one quarter, and as one tenth part of the diameter of the lumen of the corallite. The walls are homogeneous and there is nothing like exotheca or cœenchyma between them.

The natural section shows, that the corallites are of different diameters and lengths, and that they are often slightly curved and do not increase or diminish much in their course to the surface. The septa seen in the longitudinal view are thin, slightly wavy from above downwards, and sharply granular at their sides. There is a small amount of endotheca. The walls can be traced to the free ends of the corallites above, and to the sectioned corallite ends at the polished surface below. It is evident that the corallites are polygonal.

* Monogr. Brit. Foss. Corals, ser. 2, pt. iv. No. 1. Pal. Soc. 1867, p. 18.

The calices and their margins at the upper ends of the corallites the sides and walls of which have just been noticed, are slightly worn down. The outlines of the transverse views of the corallites thus given are more or less polygonal, and the walls between the lumina of neighbouring corallites are very narrow, and are inseparable, being perfectly united (fig. 2). In some instances the united walls are not thicker than one of the slender septa, and are even less than one tenth of the diameter of a corallite; in others the thickness is greater, but at this place in the corallum it never amounts to one third of the diameter. Where the state of preservation is good the crowding of the corallites and their thin walls, represented by white mineral, are very striking, and recall the parts of some modern corals when growing unusually quickly. The columella is moderate in size, styliform, and fairly circular in exact transverse section. The septa are remarkably thin, and in some places almost linear, in others they are moderately stout. The longer septa are variable in number according to the size of the corallite, and there may be eight, nine, or ten of them. The smaller septa are placed between the larger, and do not reach far inwards.

The surface of a polished transverse section of the colony made at the depth of an inch from the free surface, presents many scores of corallites, some cut transversely and others more or less obliquely to their long axes. The details of the corallites are wonderfully preserved, and one cannot but be struck with the manner in which the ancient crowding of the corallites has been rendered apparent by the variation in the calibre of the insides, and in the varieties of the polygonal outlines retained by the sections of the different individuals (fig. 3).

The shape of the corallites in transverse section is very different in the several parts of the section of the colony. The portions of the section which are evidently transverse and not oblique show polygonal shapes, the lumen often being circular.

The shapes are often quadrangular, sometimes pentagonal, frequently hexagonal, and rarely triangular. The quadrangular shape occurs in lines, and the other forms evidently depend upon irregular pressure during upward growth. Very deformed corallite sections relate to budding individuals and to those which have just become independent of the parent.

The diameter of the corallites varies from 1.25 mm. to 2.25 mm., and these measurements refer to corallites which have their full septal number; one half of the dense tissue between the lumen of one corallite and that of its neighbour is included in the measurement. This one half represents the proper mural tissue of a corallite. The thickness of the wall of the corallites measured above is one eighth of a millimetre and one twelfth of a millimetre. Thus the structure intermediate between the inside or calibre of two neighbouring corallites is one quarter or one sixth of a millimetre wide. In some parts, however, the width of the united walls may be nearly or quite equal to that of the calibre of a corallite (figs. 4, 5).

The walls of the corallites are united and fused together, and there is no intermediate structure in the form of exotheca or cœnenchyma. The markings in the hard part, the original calcareous tissue of the corallite, which denote the costæ, cross the wall as in typical *Astrocceniæ*.

The septa of full-grown corallites are twenty in number, and there are ten which join the central, styloid, essential columella, and ten much smaller which project but slightly into the calice: but some of them may unite with the larger septa at no great distance from the margin of the lumen. The larger septa in these perfect corallites are without definite cyclical arrangement, and are nearly equal in size. They are stout, straight, and slightly spinulose laterally, and may have an enlargement midway between the margin and the columella, but probably this is a result of fossilization. In some corallites this thickening is universal, in others it occurs on some septa only, and in many it is not seen. The smaller septa may unite with the larger near the columella when gemmation is imminent, and frequently no union is seen, in the largest corallites, between any septa. Usually the small septa project very slightly inwards; and they do not invariably occur between the larger ones.

Longitudinal sections show a close ornamentation of horizontal ridges and grooves on the septal laminae (fig. 9).

The path of the septa between the margin of the lumen of the corallites and the columella is always distinct; but the gradation of the septa into costæ is difficult of recognition in the section, and principally because of the existence of radiating white markings crossing the walls.

It appears, under a low power, that the majority of the whiter markings are in relation to septal commencements at the margin of the lumen of a corallite, and that they are usually continued on the walls in a line with the normal position of costæ which correspond with septa.

But sometimes the markings are between the septa at the margin, and do not correspond to costæ, and here and there the markings are in continuation with the median line of a septum. Nevertheless it may be said that the costæ are short, cover the walls, and interdigitate with those of the septa of the neighbouring corallites. There is no exotheca between them (fig. 6).

The columella is circular in outline in the transverse sections of corallites; it is usually a third of the diameter of the lumen, and is more when fossilization has added to the material of the coral. Sometimes there is a ledge of endotheca, or stereoplasm, around the columella, and it is evident that while in small calices the structure of the columella differs but slightly from that of a junction of septal ends, in most it is a well-differentiated structure. A few calices have the columella slightly elongated in transverse section. In the instances of gemmation the columella soon appears and is circular in outline, while that of the parent is often deformed.

In smaller corallites than those which have been described, the septal number varies; there may be seven or eight large septa in

calices about one half of the diameter of the largest. These septa reach the columella. Usually, but not invariably, there is a very small septum between two of the larger. Still smaller corallites have six primary septa and six very small secondary ones (fig. 7).

In no instance is there a second or third small septum between two larger and primary septa. The endotheca is scanty and the dissepiments stretch from one septum to its neighbour here and there, but the calibre is never partitioned off.

As, on account of the close contact of the walls of corallites, gemmation can only take place on the walls and from within the calice close to the margin, it is not readily discovered in sections. The best examples show a considerable increase in the diameter of the corallite and the formation of a bud with six or seven large and some small septa, the septa and columella of the parents being somewhat confused and elongated (fig. 8).

There are many broken corallite-ends to be seen on the upper part of the mass, and their being continued from those already described is evident. But with approach to the surface the thickness of the united walls usually diminishes.

In one little spot some perfect calices have been preserved, and, although weathered, they show most unmistakably the Astroccœnian character. The united walls are narrow and give indications, in every instance, of a polygonal outline. There are varying amounts of enlargement and swelling of the top of the walls, over which the costæ cross after the manner of those of other true *Astroccœniæ* *. There is no separation of the corallite-walls, and there is no instance of gemmation to be seen there.

The calices are shallow, and the columella projects slightly, and there is no crateriform and conical elevated margin.

There are some very good specimens of *Astroccœnia gibbosa* in the Museum of Practical Geology in Jermyn Street, and in one the variability of the size of the calices and of the thickness of the united walls at the surface is considerable. The polygonal shape of the terminations of the corallites is almost invariable, and when a lumen appears to be circular or nearly so, it is evident that it is included in a polygonal corallite.

The intercalicular structures, that is the united walls, are raised very generally at the corners of the calices, and the local swelling is very decided and gives a very uneven appearance to the surface. The usual dimensions of the calices is (lumen) 1 mm.; and the width of the united walls may be one half or one third of a millimetre.

In another specimen the variability of the size of the calices is striking; but they are pentagonal in outline and not circular. The united walls are thinner than in the other specimen, and are usually about one fourth of the diameter of the lumen of a calice. They are raised into decided elevations at the corners of the calices.

* No Astroccœnian has all the septa of one calice blending with those of another (Quart. Journ. Geol. Soc. vol. xxxix. p. 558), and no Jurassic species has four cycles of septa.

The costæ are crowded, and those of one calice pass on to the wall of the next corallite and interdigitate with its costæ.

A most instructive, much worn specimen, which was an old colony at the time of fossilization, is in the Museum, and in the section which has been made, it shows a few corallites cut through transversely. The lumen of one corallite is separated from that of the next one by a distance equal in breadth to the diameter of the lumen. The cause is thickening of the united walls. There is no exothecal cellular growth between the corallites, and they are united by their thickened walls. The width of the united walls of neighbouring corallites is very considerable in a specimen in the Bath Museum, on which a *Cyathocœnia* and an *Ostrea* are seen. In some places in the fossil the corallite-walls are thin, the spaces occupied by the septa and columella are small, and the lumen is often circular, especially when the walls are thick.

It is to be noticed that the transverse section of the lumen of a corallite is often circular; but the old corallite is none the less polygonal in transverse outline. It is evident that thickening of the walls occurred only during the growth of the coral, but it is apparently sometimes increased by the subsequent infilling of the outer parts of the corallite-cavity during fossilization.

The last specimen to be noticed in the Museum in Jermyn Street has the calices smaller than in the type, and some of them are triangular in outline, all the others being pentagonal, hexagonal, or square with rounded angles. The distance of the calices varies, and in some places the walls are thin and in others thick. The circular lumen, when it occurs, is within a polygonal wall in section. The costæ are unusually long in some parts where the walls are thick.

In all the forms the Astroccœnian type is maintained.

ASTROCCENIA INSIGNIS, nobis, *op. cit.* p. 19, pl. ix. figs. 1 and 2.

There is a specimen of this well-marked *Astroccœnia* in the Museum of Practical Geology, and it presents the structural peculiarities which are to be seen in the type, which is in the Bath Museum. The calices are close in places and wide apart in others, and in the first instances they are pentagonal in outline, while in the others they have a circular lumen, and this is within the polygonal walls of the corallite. The position of the junction of the corallite-walls at the surface is clearly indicated, but there is no structure between them.

The width of the united walls gave a very decided aspect to the type, especially as the costæ were stout at the end and were on the free surface. This is seen in the specimen now under consideration, and yet the opposite condition is noticed in parts.

ASTROCCENIA PARASITICA, nobis, *op. cit.* p. 20, pl. v. figs. 5, 6.

The type of this species is in the Museum of Practical Geology, and it has been carefully reexamined. The coral encrusts foreign bodies, and, in the instance of the type, a Palæozoic coral is the

resting-place. The width apart of the calices has been remarked upon, but it would be consonant with the truth to state that the calices have been worn down, and that what are now seen are transverse sections of corallites produced by wear and weather. If the specimen is compared with the section of an aged form of *A. gibbosa*, the resemblance in the position of the lumen of the corallites becomes evident. Some of the spaces marked by the septa are wide apart, and others are closer, and there has been infiltration of calcareous matter into the cavity of the corallite, which diminishes the calibre of the lumen.

In some places the lumen of a corallite may be separated from that of another by a space equal to one quarter of its diameter, in others by a space equal to a whole diameter. But no intermural cellular cœnenchyma can be traced, and it is evident that the whole structure occupying the space is mural, that the thick walls are in contact, and that they were inseparably united during life. The circular appearance of the lumen of a corallite is deceptive, and it is evident that the joined corallites were polygonal. Probably the type was a slow-growing colony, and it is quite possible that a number of individuals settled closely together, and that they united by their walls; for it is not explicable how gemmation from one parent could have produced a wide and low form*.

ASTROCCENIA PLANA, nobis, *op. cit.* p. 19, pl. v. fig. 1.

The type of the species is in the Museum of Practical Geology, Jermyn Street. It is in sufficiently good condition to show the polygonal shape of the corallites at the calicular surface, and to indicate that the calices are rather deep and separated by a varying width of more or less tumid, and invariably raised, united walls, over which rather long costæ pass. The breadth of the polygonal corallites is less than in *A. gibbosa*, and the comparatively flat surface of the corallum permits of great regularity of the lines of the calices. In no instance are there circular corallites in the central and other parts of the surface, where there is the usual crowding; and usually there is no great distance between the lumen of one corallite and that of another, except where there is a space with three or four calices in a group. The outlines of the corallites may be hexagonal or nearly square; and whilst three of them, with the walls, occupy a length slightly over three millimetres, the intermediate walls may be one third of the width of a calice, one half, or, in rare cases, two thirds. In the majority of instances the wall is only one sixth of the diameter of a corallite.

The fossilization has filled up much of the corallites, and the columellæ are therefore larger than normal. This may lead one astray in dealing with the number of septa which normally unite with the columella. The following are the numbers of septa in different calices:—(1) 10 septa all uniting with an enlarged columella; (2) 10

* See Journ. Linn. Soc. Zool. vol. vii. p. 365, 1883, for some remarks on the origin of similar colonies.

septa, six uniting with the columella ; (3) 14 septa, one half reaching the columella ; (4) 8 septa, all long ; (5) 10 long septa ; (6) 5 long and 5 short ; (7) 12 septa, but the fossilization prevents the short ones being separated from the long.

No cyclical arrangement of septa exists, and in no instance is there more than one short septum between two longer ones.

The costæ are of the same width as the septa, and usually pass between the costæ of the adjoining corallites and reach over the walls of the neighbouring corallites.

Unfortunately the specimen is too low to have a section made ; but Mr. Newton was good enough to have a part of the calicular surface ground and polished. The polished surface is not very satisfactory, but there is enough to be seen to show that the transverse sections of the corallites are mostly polygonal in outline, and that the walls of contiguous corallites are simply united without there being any cœnenchyma between them. The combined walls of neighbouring corallites vary in thickness, and it may be one quarter or one third or one half of the diameter of the lumen of a corallite, so that the thickness of one wall is not great. The shape of the lumen of a corallite in transverse section is more polygonal than circular, and the diameter varies. The condition of fossilization interferes with the comprehension of the septal development in most corallites ; but it would appear that there is great variety in the septal number. In all the corallites, when there are large and small septa, the latter are single and not in numbers between two long ones. The short septa are either straight or curved towards the larger. There is no cyclical arrangement and, except in one corallite, which is very badly preserved, there is no instance of more than twenty septa. In this particular corallite the costæ only are seen, and they indicate the presence of 24 septa. In other corallites eighteen is a common number, of which eight are small and short, the others reaching the columella. Eight long septa with four short ones is a common combination, and there is still no perfect alternation of long and short septa, the short ones being between four pairs of long ones only. In another instance there are nine long septa, and one not quite long enough to reach the columella ; besides these there are seven small septa, and three pairs of long ones have no septa between them.

It is evident that all the septa of the calices are not preserved at the free surface of the specimen, for the rubbed-down surface shows sections of corallites with more numerous septa than in the calices ; but the number is not in excess of twenty-four.

The costal markings in the section show that the costæ are continuous with the septa, that the costæ of one corallite alternate with those of its neighbours and reach over the united walls to come close to the lumen. The length of the costæ is in relation with the width of the united walls. The costæ are more distinct and longer than they are in *A. gibbosa*. The gemmation of *A. plana* takes place within and close to the calicular margin.

The figure given in Quart. Journ. Geol. Soc. vol. xl. plate xix.

fig. 2, under the name of *Stylastrœa plana*, Dunc. sp., does not correspond with the type of *A. plana*. It is not that of an Astrocœnian, for its septal arrangement, short costæ, thin walls, and intermediate cœnenchyma are not characteristic of the genus, and they are not present in any of the Infra-Liassic forms I have described. The figure is unlike a section of any species of *Stylastrœa* (see the short costæ).

ASTROCŒNIA COSTATA, nobis, *op. cit.* p. 21, pl. ix. figs. 15-17.

This species has all the generic characters of *Astrocœnia*. Nevertheless it has been placed in the genus *Stylastrœa*, E. de From., and it has been stated to be synonymous with *S. sinemuriensis*, E. de From., in consequence of the presumed resemblance of the published figures of the French and Welsh species. The following statement is made in "A Critical and Comparative Revision of the Madreporaria of the White Lias," &c. (Quart. Journ. Geol. Soc. vol. xl. 1884, p. 370):—"Any doubt that may exist as to the identity of *S. sinemuriensis*, E. de From., with *Astrocœnia costata*, Duncan, will be readily removed by comparison of fig. 7 of the former (Martin, Infra-Lias de la Côte d'Or, p. 94, pl. viii. figs. 6, 7) with fig. 16, of the latter species," in Pal. Soc. Corals of the zone of *A. angulatus*, pl. ix. figs. 15-17.

Palæontologists occasionally see differently, and therefore it is as well to read the descriptions of the forms which are represented in the drawings. It will then be noticed that the figures are not drawn on the same scale, and the calices which are stated to be identical are not of the same dimensions in nature. The French form is double the size of the Welsh. The flat view of the Stylastrœan prevents its projecting calice being shown; and this, in nature, is different from the depressed calice of the Astrocœnian. The costæ of the two forms, as shown in the figures, are positively different. The septa of the two forms differ in their number and cyclical arrangement. The figures, instead of confirming the identity, emphasize the distinctness of the forms, and this is still further proved by an examination of the morphology.

The thin walls and intermural cellular structure or cœnenchyma of *Stylastrœa* are not present in the Astrocœnian. *Astrocœnia costata*, nobis, is quite distinct from and totally unlike *Stylastrœa sinemuriensis*, E. de From.

ASTROCŒNIA SUPERBA, nobis, *op. cit.* p. 21, pl. ix. figs. 3-5.

This well-marked Astrocœnian has fine costæ, and it is only necessary to remind those palæontologists who have seen and handled the form in the Museum at Bath, that the artist has chosen for illustration a part of the corallum in which the costæ do not interdigitate so much as elsewhere. This species is stated, in the critical memoir above cited (p. 370), to be identical with *Stylastrœa Martini*, E. de From. "After an examination of the type specimen of *A. superba*," says the author, "I am perfectly satisfied of its identity with the previously described *Stylastrœa Martini*, E. de From., to which species

I therefore refer it." As no reasons relating to the morphology of the forms are given, the following facts may show that the two species are perfectly distinct and belong to different genera. It is right that I should state that since this synonymy has been asserted, I have again carefully examined my old type at Bath. Its calices are one half of the dimensions of those of *S. Martini*, and the cyclical arrangement of the septa seen in the Stylastræan is not present in the Astroccenian, which has the usual ten long and ten short septa of adult *Astroccenia*. The method of gemmation differs in the forms, and the projecting calice of the Stylastræan and the exotheca between its walls are not present in the Astroccenian. *Astroccenia superba*, nobis, is therefore distinct from the form described by M. de Fromentel, a form with which I was acquainted when I wrote the Memoir for the Palæontological Society in 1867.

ASTROCCENIA MINUTA, nobis, *op. cit.* p. 22, pl. ix. figs. 18–20.

The polygonal corallites, rarely with circular and usually with polygonal calices, separated by no great amount of united wall, are thoroughly Astroccenian. The calices are small and deep, and they do not project after the manner of *Stylostræa*; on the contrary, they are separated by raised edges and are deep. The paliform teeth which were described by me, are large and are on the septa, and the columella is small. There is no better example of an Astroccenian, and it is impossible to admit the species into a genus with which it has no alliance. The species has been called a Stylastræan in the critical essay mentioned above, and the resemblance to a *Stylina* from Azzarola and to the typical species of *Haldonia*, nobis, has been asserted in the same communication. The paliform teeth were mentioned by me, and the small size of the calices also as the distinctive characters, although this does not appear from the criticism of the corals of the White Lias, &c. p. 371.

It is stated there that "both show a remarkable resemblance in the above respect to the coral from the Greensand of Haldon, which has been made the type of the genus *Haldonia* by Prof. Duncan." The words "above respect" refer to "the paliform tooth on each septum in close proximity to the columella." Now in the first place, in its structural characters, *Astroccenia minuta* is generically distinct from any *Stylina* from Azzarola, and it is evident that if the form were a *Stylina*, it could not possibly be placed in the genus *Stylostræa*. Then it is to be noticed in the description and drawing of *Haldonia Vicaryi*, nobis (Quart. Journ. Geol. Soc. vol. xxxv. p. 91, pl. viii. figs. 2, 3), that there are pali before the primaries. The pali, as seen in the plate, are remarkable for their rugged sides, and they are not paliform teeth or appendages to the upper and inner parts of septa, but independent structures. There is therefore no structural resemblance between the paliform teeth of *Astroccenia minuta* and the true pali of *Haldonia*, a genus which is moreover different from *Astroccenia*, for it has no columella and the dissepiments are almost tabulate.

I replace *Astroccenia minuta*, nobis, in its original position.

ASTROCŒNIA PEDUNCULATA, nobis, *op. cit.* p. 20, pl. v. figs. 7-9.

Mr. Tomes further states (p. 371) that he is only acquainted with this species "through Prof. Duncan's figures, and a very cursory inspection of the type specimen;" but he places it in the genus *Stylastræa*. The form has none of the characters of the last-named genus, and the space between the calices is not filled up by thin walls with intermediate cœnenchyma, but by thick walls, united inseparably and without any exothecal structure between them; therefore the description I gave of the form is correct and the classificatory position also. *Astrocœnia pedunculata*, closely allied to *A. parasitica*, nob., remains a member of the Infra-Lias fauna.

Finally *Astrocœnia favoidea*, nob., is singularly Astrocœnian, and the narrow united walls and polygonal calices are characteristic.

Conclusion.

The whole of the specimens of *Astrocœniæ* which have been noticed in this communication, and all the others which were described in the Palæontographical Society's Monograph already alluded to, have the generic characters of *Astrocœnia* well shown. The prismatic corallites united by their thick walls in the adult condition, the small calices usually polygonal in outline, the essential styloid columella, and the number of alternate long and short septa, are easily recognized.

The character of the costæ is that of typical *Astrocœniæ*, and as the width of the intercalicular walls varies, so the length of the costæ is not the same everywhere. The gemmation is either just within the calice or on the top of the wall close by (fig. 8).

In no instance are the walls joined by exothecal structures. There is no cœnenchyma between the walls. The septa are not in any cyclical arrangement, and several septa are not seen between two long ones which reach the columella. In no instance have the calices conical crateriform shapes and raised thin and projecting margins. There are none of the special generic characteristics of *Stylastræa* or of *Stylina* present.

It appears that, owing to greater or less vigour of growth and to the influence of crowding, the corallites may be perfect hexagonal prisms, or irregularly polygonal in transverse section, and that the walls of corallites in the same corallum may be very thin at the calicular surface and thick lower down, or thick at the calicular surface and forming with their joined neighbours a mural or intercalicular cœnenchyma of varying width (figs. 1-5)*.

* These joined walls form mural cœnenchyma, and it resembles that of *Pocillopora* and some of the Oculinidæ, especially of the base of *Amphihelia* and the stem of *Astrohelia*, figures and explanations of some of which were given by myself in 1865, and long previously by Milne-Edwards and Jules Haime (Introductory Monograph, Pal. Soc. 1865-6, pl. iii. figs. 8, 9; Hist. Nat. des Corall. vol. i. pl. D, l. fig. 8a). The term *mural cœnenchyma* and its equivalent *intercalicular cœnenchyma* were used by those authors in 1857. It is totally distinct from the *intermural cœnenchyma* of such forms as the

Fossilization has rendered the original hard parts of the corals very dense and white; where there has been exposure to weather the tint is reddish or rusty. The original interspaces, or the interseptal loculi, are filled with a more or less transparent calcite, which is often coloured. Some of the septa and the columellæ of some corallites have been enlarged, as it were, by the accretion of dense white mineral, and the swollen appearance thus given is very curious. In places a deposit has diminished the diameter of the cavities of the corallites. The endotheca is in small quantity, and the septal laminae have parallel ridges on them, which, in longitudinal sections, contrast remarkably with the dense structureless fused walls which form the mural cœnenchyma (fig. 9).

This examination of a new specimen of *Astroccœnia gibbosa*, nobis, and the reexamination of the types of the other species of *Astroccœnia*, which were described in the "Monograph of the Corals of the Zone of *Ammonites angulatus*" (Pal. Soc. 1867), proves that there is nothing to justify the forms being removed from the genus in which they were placed by me.

It has been shown that in the younger parts of the *Astroccœnie* the thick united walls of the adult stage are replaced by thin and narrow walls, and that the calices are shallow and not on the top of conical elevations. It has been confirmed that the septal arrangement is peculiarly Astroccœnian, and that perfect cycles of septa are not to be determined after the form leaves the young condition. The gemmation of *A. gibbosa* has been shown to conform to the Astroccœnian arrangement, and to take place, not between the walls (for that is impossible), but where it was stated to occur in the former Monograph. The growth of a bud is shown to commence within the range of the septa or at the margin of the lumen of a corallite.

Finally there are none of the characteristic structures of *Stylastrœa*, E. de From., in the Infra-Liassic forms which were described as *Astroccœnie* by me in 1867.

DESCRIPTION OF PLATE VIII.

Fig. 1. *Astroccœnia gibbosa*. Duncan, part of a corallum (colony), showing the walls of adjoining corallites united to form a dense homogeneous mural cœnenchyma, *c*, except where a narrow line between the walls indicates incomplete fusion. The dark portions are interseptal loculi, *a*. $\times 5$.

2. Calices more or less worn. $\times 12$.

3. Part of a transverse section of the corallum. $\times 3$.

4. Longitudinal view of a part of the corallum where growth has pro-

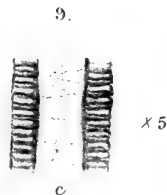
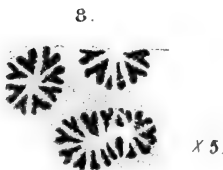
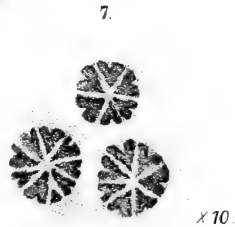
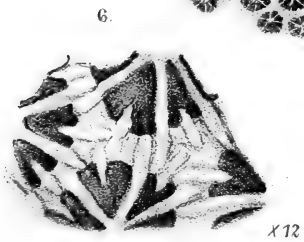
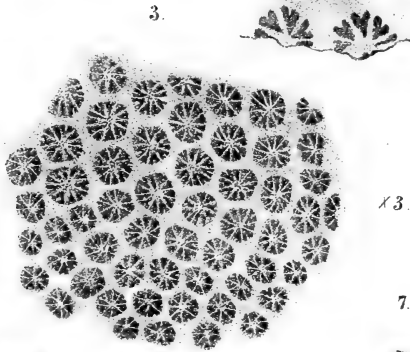
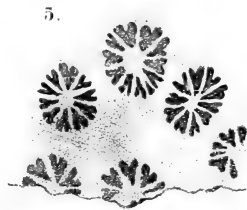
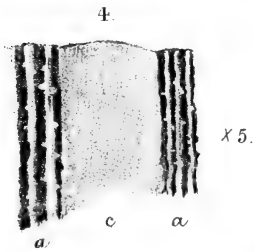
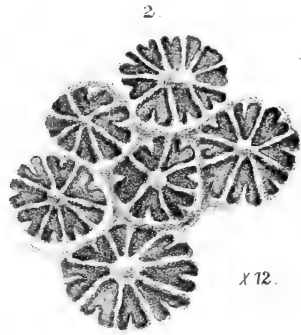
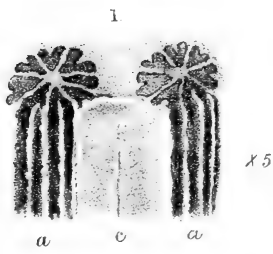
Stylinaceæ, where (take the instance of *Stylina Delabechii*) there is a greater or less amount of exothecal cellular growth between the walls of corallites. The drawing of the *Stylina* (in Brit. Foss. Corals, Ed. & Haime, Pal. Soc. Oolitic Corals, pl. xv. fig. 1) illustrates this intermural cellular cœnenchyma, and a similar structure was admirably figured by De Wilde in the Monograph on the Brit. Foss. Corals, 2nd ser. Pal. Soc. 1866, pl. vi.

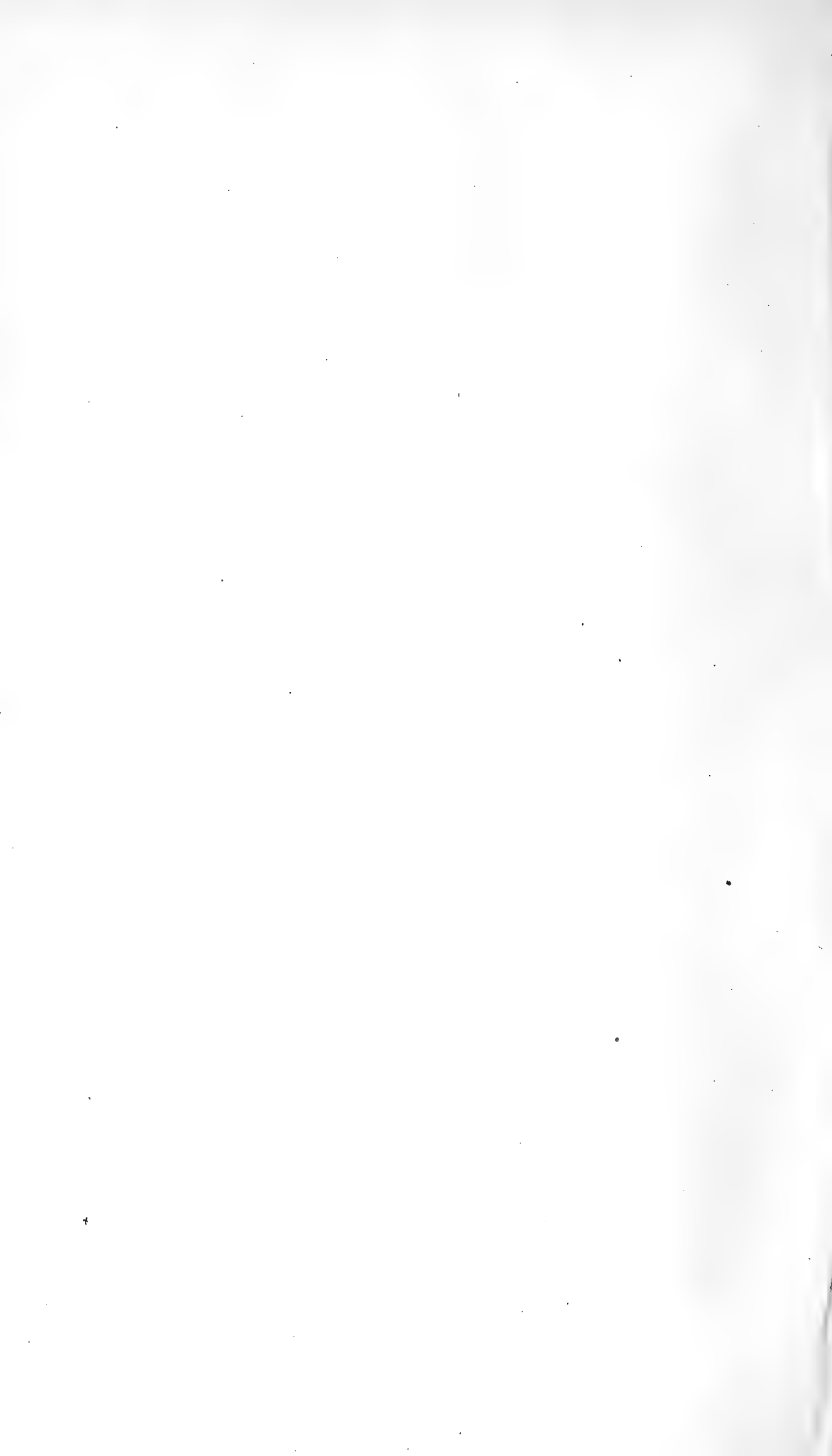
ceeded longer than in the part represented in fig. 1, showing a wide mural cœnenchyma without a trace of the once separate walls, their fusion being complete. $\times 5$.

- Fig. 5. Corallites in transverse section, showing mural cœnenchyma. $\times 5$.
6. The costæ of adjacent corallites from a transverse section. $\times 12$.
7. Section of immature corallites. $\times 10$.
8. A corallite budding within the lumen, and deformation of the parent. $\times 5$.
9. Ornamentation of the sides of septa and the mural cœnenchyma (*c*). $\times 5$.

(Drawn from nature.)

(For the Discussion on this paper, see p. 142.)





9. *On the STRUCTURE and CLASSIFICATORY POSITION of some MADREPORARIA from the SECONDARY STRATA of ENGLAND and SOUTH WALES.* By Prof. P. MARTIN DUNCAN, F.R.S., F.G.S., &c. (Read November 4, 1885.)

THE Madreporaria of the Secondary strata of England were first described in the volumes of the Palæontographical Society by MM. Milne-Edwards and Jules Haime*, and some supplementary monographs were written by the author of this communication and published by the same Society during 1866-1872.

Ten years after the appearance of the last of the monographs a series of papers was communicated to this Society by Mr. R. F. Tomes, F.G.S., and these contained descriptions of new species and genera, besides numerous criticisms of the work of the great French authors and of my own labours. The criticisms occupy considerable space in the 'Quarterly Journal of the Geological Society.' Many of them have been answered in a "Revision of the Families and Genera of the Sclerodermic Zoantharia"†; but the time has now come when a reply should be placed before this Society.

As there was no particular order in Mr. Tomes's communications, it is proposed to consider them in geological order, and the first to be noticed is entitled "A Critical and Comparative Revision of the Madreporaria of the White Lias of the Middle and Western Counties of England and of those of the Conglomerate at the Base of the Welsh Lias" (Quart. Journ. Geol. Soc. vol. xl. 1884, p. 353).

In this communication a number of genera and species were passed in review, and amongst them the species of the genus *Astrocœnia*, which were described by me in the 'Monograph of the British Fossil Corals,' 2nd series, Pal. Soc. Lond., part iv. no. 1, 1867.

Some of the species described were very typical of the genus, and most of them proved that, owing to a greater vigour of growth in some places than in others, the united walls were thin and elsewhere thick, and that the calices were pentagonal and here and there circular in outline. In no instance could a thin wall be found around a calice separated from the walls of neighbouring calices by a cellular or coenenchymal tissue. All this can be readily seen in the types, and the delineations by De Wilde are very fair.

In an essay ‡ on the Madreporaria of the Great Oolite, which preceded that now under consideration by a year, the following footnote appeared. Mr. Tomes wrote:—"I take the present opportunity

* Pal. Soc. Lond. 1850 and 1851.

† Journ. Linn. Soc. Lond., Zoology, vol. xviii. (1884), "A Revision of the Families and Genera of the Sclerodermic Zoantharia," &c. As this book will be frequently referred to, it will be termed "The Revision of the Genera."

‡ Quart. Journ. Geol. Soc. vol. xxxix. 168, &c., p. 187.

of observing that I regard some of the so-called *Astrocœniæ* from the South-Wales Lias as clearly referable to another genus." No reason was given and no argument was brought forward in order to substantiate this statement.

In the communication now under consideration (p. 369) the author, ignoring the morphological arguments brought forward by me* to explain the placing of the Infra-Lias forms in the genus *Astrocœnia*, wrote as follows:—

“ GENUS *STYLASTRÆA*, E. de From.

“This genus was created in 1860 by M. de Fromentel for the reception of two species of composite corals from the *Amm.-angulatus* beds of the Lias of the Côte-d’Or. It is characterized by circular calices, *which are not united by their walls* †, but by cœnenchyma, having costæ which are non-confluent and denticulated, by septa which are exsert and strongly denticulated, and by a well-developed and styliform columella. That some, if not all, of the so-called *Astrocœniæ* from the Sutton-Stone and Brocastle deposits in South Wales are referable to this genus, whatever may be its affinities, I do not entertain the least doubt.”

The affinities cannot be omitted, however, from the argument, and, moreover, the above diagnosis is incomplete.

It does not give the whole of the facts, and they will be found in De Fromentel’s ‘Introduction à l’étude des Polypiers Fossiles,’ 1861, p. 223:—“Ce genre correspond exactement aux Stylines et n’en diffère que par ses cloisons dentées.” He gives the following positive diagnosis:—“Corallum of a rounded form. The calices project, are circular, and united by the great development of the costæ. The costæ are broad, and pass to meet, but not to become confluent with, those of the neighbouring corallites. The septa are regularly and strongly dentated; the columella is styliform and well developed. The walls are not hidden by the septo-costal rays. The gemmation is between the calices.” The species were first of all described by De Fromentel in Martin’s ‘Infra-Lias de la Côte d’Or,’ p. 94, pl. viii.; the position of the gemmation is indicated, and it is clear that the walls of the corallites are united by more or less cellular exotheca, constituting a cœnenchyma, as in *Stylina*.

The species of *Stylastræa* have projecting circular calices, a great development of the costæ, thin walls united by a cœnenchyma, and extra-calicular gemmation. The arrangement of the septa is in definite cycles.

The *Stylastræans* are nothing more than *Stylinæ* with dentated septa, and the South-Wales corals which were placed in the genus *Astrocœnia* are generically distinct from them.

This may be understood from what has already been stated above, and the proofs are also to be found in a communication “On the *Astrocœniæ* of the Sutton-Stone and Equivalent Deposits of the Infra-Lias of South Wales,” which precedes this reply. In that essay

* *Op. cit.* pp. 24-26. † The italics are inserted by the author of this reply.

the whole of the species are replaced in their original generic environment (*ante*, p. 101).

Genus CYATHOCÆNIA, Dunc.

This genus is criticized by Mr. Tomes (*op. cit.* p. 372), and is said to be the same as *Phyllocœnia*, Laube. But an examination of *Phyllocœnia*, Laube, shows it not to be the same as *Phyllocœnia*, Ed. & H., which had precedence in time, and to which Laube really intended to refer his form.

Cyathocœnia differs from the form described by Laube under the generic title of *Phyllocœnia*, which it had not properly, for in the St.-Cassian form there is a remarkable development of the exotheca, which forms a double wall to the corallites. This takes the genus into the neighbourhood of *Diplocœnia*, E. de From., and far away from *Cyathocœnia*. The form described by Laube has been the subject of comment in the "Revision of the Genera of Madreporaria" (Linnean Soc. 1884), and it is now included as a new genus, *Koilocœnia*. *Cyathocœnia*, nobis, therefore remains as a genus of the Infra-Lias.

"CYATHOCÆNIA DECIPIENS, Laube, sp." (R. F. Tomes, *op. cit.* p. 372).

This is the name given to a single specimen. The figure shows that the specimen may belong to a species of the genus *Cyathocœnia*, in which Mr. Tomes has placed it; but it is not of the same species or of the same genus as the form described under *Phyllocœnia decipiens* by Laube. It is very curious that the peculiar structure of the double wall of the St.-Cassian form did not strike Mr. Tomes, for it is well drawn by Laube, and its existence separates the form from *Phyllocœnia*, auct., and *Cyathocœnia*. *C. decipiens*, Laube, sp., = *Phyllocœnia decipiens*, Laube, is therefore not a member of the Infra-Liasic fauna at present, and the scanty details of the figure (R. F. Tomes, *op. cit.* plate xix. fig. 3) indicate that the specimen is a very indifferent one.

Genus THECOSMILIA, Ed. & H.

The interesting peculiarities of the species of this genus, which are found in the Sutton-Stone, Brocastle, and other Infra-Lias deposits, and their comparison with the allied species from St. Cassian, were fully considered in my Monograph published by the Palæontographical Society* and in a paper read before this Society †.

There are some exceptions taken to my work. In the first place Mr. Tomes asserts that *Thecosmilia Martini* and *T. Michelini* (both found in the Hettangian of Europe) are absent. But both of these well-marked Infra-Lias species were figured and described by me in the Monograph; and they came from the late Mr. C. Moore's collection, and are now in the Museum at Bath. They are important, for their presence diminishes the value of Mr. Tomes's data, which would give a Triassic age to the Sutton Stone and associated deposits.

* Brit. Foss. Corals, 2nd ser. pt. iv. 1867, p. 11.

† Quart. Journ. Geol. Soc. vol. xxiii. p. 12.

Mr. Tomes (*op. cit.* p. 364) omits to mention that *T. rugosa*, Laube, was first recognized by me as a British fossil and described and drawn in the 'Monograph on the Fossil Corals' from the zone of *Ammonites angulatus* (Pal. Soc. 1867, p. 13). The figures in the Monograph show the characters of the species, but no additional knowledge is given in the memoir under review, and, in fact, the illustration in the Quart. Journ. Geol. Soc. vol. xl. pl. xix. fig. 1, might serve for several species. There is nothing distinctive about it, except the stunted form to which attention was drawn nearly twenty years since.

THECOSMILIA HORNERI, Laube.

This is recognized in the essay under consideration from a cast, and a drawing is given of it (pl. xix. fig. 8). It is compared with some forms described in the "Monograph of the Corals," zone of *Amm. angulatus* (Pal. Soc. 1868, pp. 67, 68, figs. 3 and 6), and they are said to be unfavourable examples of casts of the same species. But whilst the figure 6 differs totally from that given by Mr. Tomes, figure 3 illustrates what is very evidently a cast of a young coral which cannot possibly be named. The evidence of the occurrence of *T. Horneri*, Laube, in the British fauna is insufficient.

THECOSMILIA CONFLUENS, Laube.

It is perfectly well shown by Mr. Tomes (*op. cit.* pl. xix. fig. 7) that the fragment upon which this species was attempted to be placed in the White Lias of England, is not a portion of a Thecosmilian.

THECOSMILIA MIRABILIS, Dunc.

It is distinctly stated (Pal. Soc. 1867, Monogr. Brit. Foss. Corals, pt. iv. p. 12) that the corallites do not increase by fissiparity, and the figure (pl. ii. fig. 10) proves that gemmation occurs.

THECOSMILIA SERIALIS, nobis.

This well-marked species was well drawn by De Wilde in my Monograph. The coral was mistaken by Mr. Tomes for a species of *Elysastræa*, and subsequently acknowledged by him to belong to the species under which I had placed it.

Subgenus CLADOPHYLLIA, Ed. & H.

MM. Milne-Edwards and Haime notice that this group is not very sharply defined from that called *Thecosmilium*, Ed. & H. In the "Revision of the Genera" the species formerly admitted into it are placed in *Thecosmilium*, in the subgenus *Cladophyllia*. One of the characters of the old genus was that the calices are deep (Hist. Nat. des Corall. vii. p. 363), yet some shallow-caliced forms found by Mr. Tomes are placed by him in it. This cannot be correct, and the form he alludes to on p. 367 as *C. sublaevis*, Laube, is undefinable.

Genus ELYSASTRÆA, Laube.

Two species of this genus were determined by me to occur in the

Sutton Stone, and one was clearly the same as that described by Laube from St. Cassian *. The other was specifically distinct, and it had fewer and stouter septa in calices of the same size as those of the other form; moreover the separation of the corallites was more definite. On due consideration I do not feel disposed to abolish the second species (*E. Moorei*), especially as a remark in the memoir on "the Madreporaria of the Lias" leads to the belief that its author is not treating of the genus. He compares parts of the corallum with *Latimæandra*, with which the types have no affinity. I therefore retain both of the species of *Elysastræa*.

Genus MONTLIVALTIA, Lmx.

MONTLIVALTIA SIMPLEX, nobis.

This species was described and figured in the "Monograph on the Corals from the zone of *Ammonites angulatus*," p. 9, pl. iii. figs. 16 & 17, and is admitted by Mr. Tomes in his criticisms on the corals of the zone; but a remark is appended to which exception must be taken. It is stated that the "much elongated form of the calice, and the angle observable in some of the septa, are merely the result of pressure."

The shape is not much elongated, only moderately so, and the cause was the special method of growth of the cycles of septa, examples of which are seen in modern simple corals, such as *Caryophyllia*. The shape of the ends of the septa depends on growth, and is seen in many species even of cylindrical form. The shape has nothing to do with pressure after death.

MONTLIVALTIA WALLÆ, nobis.

The author of the paper on the Lias corals admits this form, and adds that the describer "might further have noted the continuity of the older septa from the outer rim through the inner wall in the calice proper." In the very next sentence it is remarked that this is "well shown in Prof. Duncan's figure;" but the critic goes on to state that this (Monograph *cit.* pl. viii. fig. 6) "is a good illustration of rejuvenescence." As this expression will have to be considered elsewhere in this reply, it is only necessary for me to remark here that it is nothing of the kind, being an instance of that endothecal growth which Lindström has called "stereoplasm."

MONTLIVALTIA POLYMORPHA, Terquem and Piette.

This is figured on pl. viii. of my Monograph. There is no better example of a *Montlivaltia* than in fig. 1. Fig. 13 shows two forms springing from the same base. Mr. Tomes, although he admits that he cannot make out the calices of the last-mentioned specimen, because they are (as they were drawn) imbedded in the matrix, places the forms in the genus *Thecosmilia*, and under the species *T. major* of De Ferry (*op. cit.* p. 367). He gives no

* Monogr. *cit.* p. 29.

reason, and states that "it is difficult to determine with certainty to what species it should be referred." Under such circumstances it would have been as well if he had proved by facts capable of verification that the form belonged to De Ferry's species. *Montlivaltia polymorpha* therefore remains a member of the Infra-Lias fauna of England, and *Thecosmilia major* is still a stranger. Mr. Tomes refers *M. polymorpha* to me; it is a species of Terquem and Piette.

MONTLIVALTIA PEDUNCULATA, nobis, *op. cit.* p. 10, pl. ii. figs. 12, 13.

This is a well-defined species of pedunculate *Montlivaltia*, and is characterized by its high septal number. It is of course a simple coral, and the calice is worn down in the type. A second form of the same species is given in the Monograph, pl. viii. fig. 16, allowing for the variation which was as common in *Montlivaltia* as it is in recent simple corals. This species has been misplaced in the genus *Cladophyllia* (Tomes, *op. cit.* p. 367), which does not include simple corals, and it is associated with *C. subdichotoma*, Laube; this is also an error which has arisen from confounding two distinct forms.

Montlivaltia pedunculata remains, then, as a member of the Sutton-Stone and Brocastle fauna.

In the amended list of the corals from the White Lias, Sutton Stone, Brocastle, and other beds Mr. Tomes omits *Montlivaltia Murchisonæ*, nobis, a very well-marked species, the curious little *Montlivaltia parasitica*, nobis, and *M. brevis*, nobis. These species are figured and described, and have the true Infra-Lias facies. They remain members of the fauna.

The position of the Sutton-Stone and Brocastle deposits is, in my opinion, not amongst the deposits below the zone of *Avicula contorta*; they are neither St. Cassian nor Rhætic. The proof is that the Mollusca and many of the corals of the strata on the continent above the *Avicula*-zone and in the Infra-Lias are identical with those of the Sutton-Stone, Brocastle, and other deposits on the same horizon. Those Mollusca which were determined by me (Duncan, "Infra-Lias, South Wales," *Quart. Journ. Geol. Soc.* vol. xxiii. p. 12) were not separate from the corals, as is supposed, but most may be seen on the same blocks in the Museum at Bath.

The second communication to which attention is requested, was read by Mr. Tomes on May 9, 1877, and relates to "The Stratigraphical Position of the Corals of the Lias of the Midland and Western Counties of England and of South Wales" (*Quart. Journ. Geol. Soc.* xxxiv. 1878, p. 179). The figures given in the plate which accompanies the paper show that the specimens, with one or two exceptions, were in a very poor condition.

One of the most interesting of the corals is a *Montlivaltia*, which was found perfect, from the White Lias (*M. rhætica*, Tomes). The description shows that it is a well-characterized form, but it was not figured. Had the species been drawn, it would have been seen to have decided differences from the cast of a *Montlivaltia*

which was figured in my Monograph of the Liassic Corals ("Corals from the zone of *Ammonites angulatus*," p. 68, Pal. Soc. 1868). I there noticed a cast of a multiseptate discoidal coral of the genus *Montlivaltia*, which was found at Punt Hill, Warwickshire, and I believed it to belong either to *M. Haimeii*, Ch. & Dew., or to one of the varieties which I had previously described and drawn. Now Mr. Tomes states (p. 181), "After a careful examination of a great many specimens, I have arrived at the conclusion that it is quite distinct from that species, and I describe it thus." The description of a form, which has already been stated to be well characterized, is then given. But are the better-preserved specimens, of which Mr. Tomes has examined so many, the same as the type I figured? On looking at the drawing in my Monograph no one can doubt the similarity of the cast which it represents to one of *M. Haimeii*; and even the spiny ornamentation and septal number are identical. On the other hand, when the form named *M. rhætica*, Tomes, is studied, from the description of its author, it appears that in a cast it could not present the appearances which the form I have drawn certainly does. In *M. rhætica* the primary septa are strongly developed, and meet and unite in the centre. No such large septa are in the cast, and the septa do not unite in the centre. There are four cycles in the *M. rhætica*, and the fifth is merely rudimentary, according to its describer; but in the cast the fifth cycle must have been as well developed as it is sometimes in *M. Haimeii*. It is evident, then, that Mr. Tomes's coral is not of the same species as the cast figured, and placed as *M. Haimeii*.

MONTLIVALTIA FOLIACEA, Tomes, *op. cit.* p. 191.

There are portions of the description of this species (which is so badly drawn that nothing can be comprehended about the septal number) that are clear, and enable it to be readily identified. But there is evidently an error made regarding the septa. In the description it is stated, "There are nine cycles and six systems." Then the nature of each cycle is given, and it is stated that "the ninth cycle has septa which are one fourth of the length of the primary ones." The diameter of this coral was one inch. There is no instance of a coral having nine cycles, and such a number is not even found in the largest modern *Fungia*, some of which are six inches across. Now nine cycles of septa will number in the six systems no less than 1536 septa, or in one system 256 septa!

It is perfectly incomprehensible how this error can have been made; but it is not an isolated instance of the misapprehension of the cyclical arrangement of *Montlivaltia*.

Mr. Tomes does not give a figure of his new species, *M. excavata* (*op. cit.* p. 192), and yet it has a septal anomaly. It is said to have five cycles, and that the fourth and fifth cycles are rudimentary. This has not occurred in any described species previously; and it is invariable that when the fourth and fifth cycles are found, the fifth may be rudimentary, but never both. Again, in the drawing of *M. papyracea* (Tomes, *op. cit.* pl. ix. fig. 9) there are only four cycles,

and the fourth is, in places, rudimentary; but in the description of the species it is a fifth cycle that is rudimentary.

An essay "On the Madreporaria of the Inferior Oolite of the neighbourhood of Cheltenham and Gloucester" appeared in the Journal of this Society in 1882 (Quart. Journ. Geol. Soc. vol. xxxviii. p. 409). I might almost have contented myself with directing the attention of the Society to the reply I made at the close of the reading of this communication; but unfortunately its author persisted for a long time in maintaining what was shown to be an error, and about which there is now no second opinion, namely, the classification of *Thamnastræa* in the section Porosa. The whole of the subject has been noticed in the "Revision of the Genera," p. 136.

Any naturalist who is desirous of advancing the scientific knowledge of fossils by a philosophical criticism should be well acquainted with the standard work of Milne-Edwards and Jules Haime (Hist. Nat. des Corall.); but this work seems not to have been familiar to Mr. Tomes, for he makes a strange error in the course of his criticisms in reference to their work on the group of the *Thamnastræa*. The genera or subgenera *Synastræa* and *Centrastræa* (he writes) were proposed by M. de Fromental (p. 435); but the first was a creation of Milne-Edwards and the last of d'Orbigny. M. Milaschewitsch described species of *Astræomorpha*, Reuss, from Nattheim, and although none have been found in England, Mr. Tomes remarked that it corresponds with *Centrastræa*, which is a *Thamnastræa* with a styliform columella. Now there were few abler observers than Reuss, and he would have been the last to have confused *Astræomorpha* and *Centrastræa*. Pratz* has shown that M. Milaschewitsch was mistaken, and that *Astræomorpha* is not an Oolitic but a Triassic genus, and has distinguished it from *Centrastræa*, and, indeed, Reuss did the same. It is necessary to place *Astræomorpha* and *Thamnastræa*, with its subgenera, in different alliances (this subject is more fully considered in the "Revision of the Genera," &c. p. 135).

Several species of *Oroseris* were described with much care in the essay under consideration; but it is impossible to agree with the author's views of the genus. The sentence in which the author indicates his opposition to the views of Milne-Edwards and Jules Haime, d'Orbigny, Reuss, and myself, and in which he not only separates *Oroseris* from *Comoseris* most definitely, but also allies it with a genus which he places in the Perforata, shows that he does not study with the aid of that systematic morphology which we owe to the great French zoophytologists.

In this instance the author even opposes M. de Fromental, who places the two genera close together, and not amongst the Perforate corals. The following is the quotation (R. F. Tomes, *op. cit.* p. 440):—"Genus *Oroseris*, Edw. & Haime. This genus was associated by its original describers with the genus *Comoseris*, to

* E. Pratz, Palæontographica, 1882, p. 103, *et seq.*

which it really bears but a faint resemblance." On p. 434, is the heading "*Zoantharia Perforata*," and "*Oroseris*" follows (p. 440).

It has been shown, in the "Revision of the Genera," pp. 162, 163, that *Oroseris* should become a subgenus of *Comoseris*, d'Orb., and that it cannot be a perforate coral as Mr. Tomes has stated. In order to save space, reference is therefore made to that work. But it is necessary to remark that although the great distinction between the two groups is the difference in the length of the collines, Milne-Edwards and Jules Haime recognized the occasional existence of "calices épars," amongst the others which are in series, in 1860, Hist. Nat. des Corall. vol. iii. p. 79 (under *O. apennina*), just as Mr. Tomes did in 1882. In the descriptions of the species of *Oroseris* Mr. Tomes has correctly shown that the epitheca may be as strong and as wrinkled as in *Comoseris*; but although he finds synapticulæ in one species (p. 442), he places it among the *Perforata* *.

Mr. Tomes's descriptions show that Milne-Edwards and Jules Haime were correct in stating that the two genera are closely allied, and not that they are very different.

GENUS *MICROSOLENA*, Lmx.

This genus was placed amongst the *Poritidæ*, a group of perforate Madreporaria, by Edwards and Haime. Species were examined by Milaschewitsch and were placed by him with *Thamnastræa* among the *Perforata*. The author of the work now under consideration agrees. But good specimens of *Microsolena* have clearly, in addition to their beautifully perforate septa, a host of delicate synapticulæ in their interseptal spaces, after the manner of the *Fungidæ*. Hence it has been necessary to place the genus in the section *Fungida*, and in a family distinct from that of *Thamnastræa*, and associated with such genera as *Thamnaræa*, Etall., *Diplaræa*, Milas., and the recent genus *Mæandroseris*.

GENUS *CIRCOPHYLLIA*, Ed. & H. (subgenus *ANTILLIA*, Dunc.).

The so-called genus *Cyathophyllia*, E. de From., was not placed in "The Revision of the Genera of Madreporaria;" for with the approbation of Pourtales and Reuss it had given way to the prior genus *Antillia*, nobis. Of the identity of the forms included in the so-called and the acknowledged genera there can be no doubt, and it is true that *Antillia* was published and illustrated by me in the Quart. Journ. Geol. Soc. vol. xx. 1864, p. 28, long before M. de

* In a communication "On the Madreporaria from the Great Oolite," Quart. Journ. Geol. Soc. vol. xli., May 1885, p. 185, Mr. R. Tomes replied to statements which had appeared in the "Revision of the Genera," 1884. He endeavours to show that there is a wall in the collines of *Comoseris*, and as it is known that there is not one in *Oroseris*, he properly considers that this is a generic distinction. He finds in worn specimens of *Comoseris* that "a very distinct and continuous line is sometimes observable, *simulating* a true wall" (p. 186).

Every student who has seen a worn *Comoseris* is aware of this false wall, and it is not a true one. Hence the distinction falls to the ground. The arrangement of the calices in the two so-called genera is not of sufficient importance to give *Oroseris* more than a subgeneric position.

Fromental founded the genus *Cyathophyllia* *. Zittel, on the faith of the French zoophytologist, gives an incorrect diagnosis of *Antillia*; but Pourtales and Brüggemann found recent species, and recognized the generic attributes.

In the essay "On the Madreporaria of the Inferior Oolite," Mr. Tomes brings forward the genus *Cyathophyllia* again, although he states, "But before the creation of *Cyathophyllia*, Prof. Duncan had defined, under the name of *Antillia*, a genus which only differed from *Montlivaltia* in having a large columella." It is to be observed that the word "only" was not used by me in defining the genus, as the existence of a large essential columella is a very definite and important character. In the description of *Cyathophyllia oolitica*, Tomes, it is stated that the septa unite before reaching the columella, and this is proposed by Mr. Tomes to be a generic attribute of *Cyathophyllia*. But M. de Fromental does not give that character, and it does not exist in any *Antillia* or true *Cyathophyllia*, according to their describers. There is therefore no reason for the non-adoption of the generic term *Antillia*. On turning to the plate xviii. fig. 4, Quart. Journ. Geol. Soc. vol. xxxviii. 1882, it will be noticed by those palæontologists who have seen species of *Antillia* that the facies is not that of the genus. No section is given of the form, and there is so little to lead the student to a satisfactory generic definition of it, that any one who had studied the simple Fungida would place the form in the neighbourhood of *Thecoseris*, E. de From., the uniting and numerous septa being strong characters amongst the group. One must demur therefore to the admission of this comparatively unexamined form into the genus *Antillia* (which has precedence of *Cyathophyllia*).

In revising the genera of *Madreporaria* it was found absolutely necessary to thoroughly reconsider all the simple forms very carefully and without regard to authority. It will be found (p. 60) that *Antillia*, nobis, is placed as a subgenus of *Circophyllia*, Ed. and Haime, and that its synonyms are *Cyathophyllia*, E. de From., *Smilophyllia*, E. de From., *Syzygophyllia*, Reuss, and *Homophyllia*, Brügg.

In the essay on the Madreporaria of the Inferior Oolite and in some of Mr. Tomes's other communications mention is made of a presumed discovery of M. Milaschewitsch, and it is utilized in some criticisms of the work of Milne-Edwards and Jules Haime and myself.

At page 409, the following notice of this matter is given by Mr. Tomes:—"According to that zoophytologist [Milaschewitsch], the corallum, under certain conditions, can almost suddenly contract itself, and afterwards more or less quickly expand again and continue its existence in a new form. This M. Milaschewitsch distinguishes by the name of 'Verjüngungsprocess,' which may be translated "a process of rejuvenescence."

All this will seem very strange to the biologist who has noted the

* M. de Fromental mistakes my definition of *Antillia* (Pal. Franç. Terr. Crét. tom. viii. livr. 24, p. 293), and gives the genus a lamellar columella. In no species is this generic character to be found.

exceedingly slow growth, and the evident influence of abundance and lack of food upon the yearly growth, of recent corals of such genera as *Caryophyllia* and *Balanophyllia*, species of which may be kept in aquaria. The idea of a dense mural tissue of carbonate of lime covered with and containing soft structures, contracting suddenly and expanding again, does not commend itself to the common sense or the experience of the students of recent forms. What changes occur during upward growth are slow and are not at the discretion of the animal, as the wording of the translation given above seems to indicate; and in the method of growth of recent forms, which is summarized by naturalists under the head of "growth-ringing," and which is the old name for the "Verjüngungs-process," there is no development of a new form.

Many years since Milne-Edwards and Jules Haime called the phenomena described by Milaschewitsch "bourrelets d'accroissement," and, following them, zoophytologists have called the results of alternations of growth "growth-rings." It happens, both in the recent and fossil forms, that wearing removes the projecting part of the ring and exposes the outer part of the visceral cavity and the ends of the septa; and sometimes the older part of the wall goes on growing and slightly overlaps the starved part. In fact, the French naturalists carried the importance of this growth too far, and some species were determined from its occurrence. It is a passive process of nutrition; it has been well observed; and there is no rejuvenescence about the phenomenon. Unfortunately both the describer of the Nattheim corals and Mr. Tomes sometimes confuse the process with calicular budding, and do not discriminate the one from the other. Calicular gemmation is very common in many recent forms; and, whilst it is sometimes accidental, at other times it is apparently invariable. With regard to the genus *Montlivaltia*, it was known to the authors of the Hist. Nat. des Corall. that the species were singularly subject to "bourrelets d'accroissement," but it is not correct to state with Mr. Tomes that "under its agency forms appear which at first sight may seem to be quite distinct from *Montlivaltia*." The occurrence of calicular gemmation in a *Montlivaltia* was not recorded by the founder of the genus, neither do we find that the phenomenon enters into the generic attributes as given by Milne-Edwards and Jules Haime.

The genus *Oppelismilia* was founded by me in order to receive *Montlivaltia* which increased by calicular gemmation; and in the type the epithecal bud within the calice, and on one side, has been mistaken by my critics for an instance of rejuvenescence. Of the value of the calicular gemmation in differentiating genera there may be diverse opinions, and yet it must be admitted that it is of sub-generic value. In the "Revision of the Genera," *Oppelismilia* is placed as a subgenus of *Montlivaltia*, and *Montlivaltia turbata*, Milasch., and any forms which Mr. Tomes may have noticed with calicular budding, will come within it.

On the strength of the interesting form of growth which develops growth-rings being of primary classificatory importance, which it

most certainly is not, it is attempted to alter the classificatory position of *Axosmilia Wrightii*, Ed. and H., and *Montlivaltia Holli*, nobis, of the Inferior Oolite (R. F. Tomes, *op. cit.* p. 416). The two forms are said to belong to the genus *Donacosmilia*, E. de From. That genus may be thus defined from the 'Introd. à l'Etude,' p. 146:—

"Corallum fasciculate, reaching to a considerable height, wall with a complete epitheca, which forms circular bourrelets; calices circular. Septa broad, slightly exsert, and uniting in the centre of the calice. No columella. Dissepiments numerous and well developed." In a description of one of the species, it is noticed that the epitheca may wear and expose the septa to view close to the wall, and that, when several bourrelets are thus formed one over the other, it looks as if a set of corals had been placed one within the calice of the other.

Axosmilia Wrightii was thus named with considerable hesitation by Milne-Edwards and Jules Haime, and they stated this and the reason for their doubts in their great monograph. They never saw the inside of the specimen, nor the outside of the calice, for it was in matrix. Their figures show a short simple coral, marked not overmuch by growth-rings, and there is nothing to lead to the belief that the form was the beginning of a compound and fasciculate one.

It would have been better if Mr. Tomes had stated the opinion of the describers of *Axosmilia* in full. No one will admit that they have been proved to be wrong until the absence of a styloid columella is shown in *Axosmilia Wrightii*, and it is satisfactorily demonstrated that the simple form was going to be a compound and fasciculate one. A student of the recent coral-fauna will have no difficulty in recognizing growth-rings in the excellent figures of *Montlivaltia Holli* by De Wilde, in the 'Monograph of the British Fossil Corals,' 2nd ser. pt. iii. Pal. Soc. 1872, pl. i. figs. 5-8. The coral resembles *Donacosmilia* in two points, but they are of no great physiological importance. They are the resemblance of the outside of the corallum to the base of a species of *Donacosmilia*, and the non-existence of a columella. But the pedunculate nature of *M. Holli*, and its shape, are common to some recognized *Montlivaltia*; and the nature of the axial part of the corallum, where a columella could be formed, differs in *Donacosmilia* and in *M. Holli*. In the one the septa meet in the centre; and in the other there is a considerable space environed by the ends of the septa; and thus there is no union. But the distinctions between the form and any *Donacosmilian* are definite and generic. There is decided calicular gemmation; and this has been mistaken for rejuvenescence, or rather for the results of that process. *Donacosmilia* is a rare genus in the British fauna; and even on the Continent its species are found in a miserable condition. Indeed, it was so doubtful whether there was not a columella in the axis, that I placed a mark of doubt against it in the "Revision"*.

The nearest approach to anything resembling a *Donacosmilian* which has come under my notice, is a species of *Lepidophyllia*,

* "Revision of the Genera of Madreporaria," p. 54.

which shows all the external characters of a piece of *Donacosmia*, and which may belong to the genus, as suggested by Mr. Tomes. (Pal. Soc. 1868, Corals from the Zone of *A. Bucklandi*, p. 53.)

I disagree therefore with the statement of the identity of *Axosmia Wrightii* and *Montlivaltia Holli*; and I retain this last as I originally named it, placing it, for consistency's sake, in the sub-genus *Oppetismilia*.

Until a fossil of the genus *Epismilia* is found perfect and free from weathering and wearing of the slender tops of the septa, so long will the genus not be recognized. M. de Fromentel, in describing the genus, created it for *Montlivaltia* with smooth septa and elongate fossulæ. Therefore, a spiny-septate *Montlivaltia* which had been worn became a new generic form. Milne-Edwards and Jules Haime saw many of the forms which since the date of the Hist. Nat. des Corall. have been included in the genus *Epismilia*; but their experience led them to place a proper value on the character of the smooth septa. Elongate fossulæ are not distinctive from *Montlivaltia*. Mr. Tomes introduces a form which he states, *op. cit.* p. 415, was not in a sufficiently satisfactory state of preservation to admit of description. He then states, "The edges of the septa have been worn off." How, then, can this form be distinguished from a *Montlivaltia* which had its septa worn and weathered on top and at the sides? There is not the slightest warrant for the introduction of the genus into the fauna.

Reuss altered the name *Confusastræa* into *Adelastæa*, on account of the barbarism of the first-mentioned generic appellation; and Mr. Tomes, in his essay on the Madreporaria of the Inferior Oolite, although he retained the old name at first, properly utilized Reuss's alteration subsequently. But it is not correct to state that "the genus *Adelastæa*, Reuss, from the Cretaceous beds of Gosau, is founded upon a species of *Confusastræa*." The author of the essay now under consideration, in common with many investigators, has had great trouble with this genus. Milne-Edwards had only indifferent specimens to examine, and the same may be said in the case of d'Orbigny. Nevertheless, certain definite generic attributes were got at, and there is only a doubt about one structure. It is quite certain that the corallite-walls are rudimentary in adult forms, also that the calices are swollen in the costal part, so as to present bourrelets separated from one another by polygonal grooves, and that the costæ are continuous. In the typical species there is no columella, but Reuss has shown that a rudimentary one may exist.

It appears to me that there may be rudimentary walls in young parts of a colony.

A form was called *Clausastræa consobrina*, by Ed. and Haime, but they put a note of interrogation after the generic name, and this was added to the Crickley fauna by Mr. Tomes. He found, however, that the form he thus named really belonged to the genus *Confusastræa*, and he then proceeded to show (on p. 422) that it cannot possibly be associated with it. He states that the species has distinct walls and a pimple-shaped columella. The

walls are not simply rudimentary in the young parts of the corallum, and the columella differs from the rudimentary kind noticed by Reuss.

Unfortunately, no figure is given of the species or of the sections. Some other genus will therefore have to include this species, or rather, a species which cannot rest either in the genus *Claustræa* or in *Confusastræa* and *Adelastrea*.

ISASTRÆA TENUISTRÏATA, M'Coy, sp.

An attack is made on the value of one of the best-defined species of the Oolite, and it is evident that the criticisms regarding *Isastræa tenuistriata*, M'Coy, sp., as elaborated by Ed. and Haime, are due to Mr. Tomes having mistaken a different form for the true species so well described in the 'Monograph of the Pal. Soc.' (Ed. & H., Corals from the Inferior Oolite, p. 138, pl. xxx. fig. 1, 1a).

In the first instance, Mr. Tomes considered that some specimens of corals which he obtained from Crickley, and which he himself named *Isastræa tenuistriata*, were really to be referred to another genus. Then he decided that there was not such a thing as the above-named species, and that errors had been made. Then he writes, in the essay now before us, p. 423, "The supposition expressed by me that *Isastræa tenuistriata* was not a true *Isastræa*, has had partial confirmation by the examination of a considerable number of specimens, which show that two species have been confounded under that name."

He adds:—"The original description by M'Coy, as well as that afterwards given by Milne-Edwards and Haime, will apply to one of these, which is a true *Isastræa*." "The other is a species of *Confusastræa*." Mr. Tomes is aware that he alone is responsible for associating specimens with *Isastræa tenuistriata* which were unknown to the previous authors, and which were not called *Isastræa tenuistriata* by them. There was no error or confounding of species on the part of Milne-Edwards and Jules Haime, or of M'Coy.

Thus there is no confirmation whatever that this form is not a true *Isastræa*, and Mr. Tomes writes, p. 425, "But other specimens have occurred which are undoubtedly referable to M'Coy's *Astræa tenuistriata*," that is *Isastræa tenuistriata* of subsequent authors.

The specimens which the author of the essay on the Madreporaria of the Inferior Oolite took to be the forms described by M'Coy and his successors were, he now states, of a different genus, *Confusastræa*! A figure is given of this *Confusastræa tenuistriata* (Quart. Journ. Geol. Soc. vol. xxxviii. pl. xviii. fig. 11), and if it is compared with the drawing of *Isastræa tenuistriata* in the Monograph of Milne-Edwards and Haime, it will be noticed that they are *totally unlike*. There is no possibility of their being confounded.

The figure and the description given by Mr. Tomes indicate moreover that the form cannot possibly belong to the genus to which he has assigned it. In the drawing the main character of *Confusastræa*

or, rather, *Adelastræa*, is wanting, and the continuous and well-developed costæ are not seen.

It is clear that the corallites have walls, and that the bundle of short stick-like growth is totally different from the structure of *Adelastræa*. The generic position of this particular species is most probably in the subgenus *Cladophyllia*, and near a form described and figured by me in the "Monograph of the Fossil Corals," Pal. Soc. 1872, pl. iii. figs. 1-4, p. 3. It is not that form, but the generic attributes are the same. Finally, Mr. Tomes acknowledges that he is not even sure about the form he separated from *Isastræa* being a *Confusastræan*; he says, "I have placed this curious species in the genus *Confusastræa* with considerable doubt" (p. 424). The form cannot remain in the genus in which Mr. Tomes placed it.

There is a curious employment of a term in reference to this species which is explanatory, to a certain extent, of an incomprehensible criticism of a figure I gave of *Thamnastræa Waltoni*, Ed. & H., Pal. Soc. 1872, Brit. Foss. Corals, pt. iii. pl. ii. figs. 6 & 9.

Mr. Tomes states that the septa "all are evenly and delicately, but very distinctly geniculated." Geniculation is a term which refers to the horizontal knee-like bendings of the septo-costæ of species of such a genus as *Thamnastræa*; but there is nothing of the kind in *Isastræa tenuistriata*. Mr. Tomes seems to make the word equivalent to granulation, crenulation, or minute spinulation of the free margins of septa (see p. 134).

Although it has been necessary for me to place myself in such very definite antagonism with the author of the "Madreporaria of the Inferior Oolite," it is pleasing to have to recognize the author's careful work in some instances. In one matter it appears that we were both in error, and a species placed in the genus *Cyclolites* by myself, and in *Dimorphastræa* by Mr. Tomes, turns out, after his careful use of the graver, to be a form of *Dimorpharæa* of M. de Fromental. The synonymy of *Dimorpharæa* I have noticed in the "Revision of the Genera," p. 170.

Mr. Tomes has worked off the matrix, and has exposed the central calice and a well-marked row of surrounding calices which were not visible previously. *Cyclolites Lycetti*, nobis, becomes, therefore, *Dimorpharæa Lycetti*, Dunc., sp., and *Dimorphastræa dubia*, Tomes, is absorbed. This is to be regretted, because, in the description of the species, Mr. Tomes, having better specimens, was much nearer the truth than I was.

Genus CHORISASTRÆA, E. de Fromental.

The late A. E. von Reuss did not see the propriety of recognizing this genus, nor did Milne-Edwards and Jules Haime.

The genus *Chorisastræa* was founded in error, as Pratz has proved*, and it was intended to break up the genus *Latimæandra* as diagnosed by Milne-Edwards and J. Haime. These naturalists had carefully studied the forms which, before the time of their great work, had been associated with no less than five genera by d'Orbigny, and, in

* Palæontographica, 1882, p. 109, note. See also "Revision of the Genera," p. 127.

their Hist. Nat. des Corall. vol. ii. p. 543 and 544, they finally elaborated the genus *Latimœandra*.

They did not see the necessity for eliminating the species the walls of which are not perfectly united up to the margin of the series of calices, and therefore they placed in the genus such forms as *L. Bertrandii*, J. Haime, which has incompletely united series, *L. Michelotti*, J. Haime, which has the series sometimes closely united and sometimes has them disunited, and *L. Flemingi*, Ed. & H., which has a solid corallum with union of the valleys.

Stoliczka's opinion is worth recording. Referring to *Latimœandra* ("Cretaceous Corals of S. India," p. 37, Pal. Indica, 1873), he says:—"There can be two sections distinguished, the one called *Chorisastrœa* by De Fromentel, in which the calices are separated from each other by more or less distinct depressions, and the second, or *Latimœandra*, in which the series of calices are separated by united ridges, over which the costæ pass without interruption. These two sections are so intimately connected with each other that authorities on the subject, like Milne-Edwards or Reuss, do not consider a separation into two genera practicable."

To add to the confusion produced by the adaptation of the so-called genus *Chorisastrœa* to serial Corals as well as to *Latimœandra* which increase by calicular budding, an attempt was made to include the well-known species of *Thecosmilia*, which at first increase by gemmation and then by fissiparity. De Fromentel's generic diagnosis did not permit of this extension, which has led to error. For the drawing of *C. gregaria*, M'Coy, sp. (R. Tomes, *op. cit.* pl. xviii. fig. 3), although it is figured to indicate the absence of union of the walls of the specimen, the species being said to belong to *Chorisastrœa*, shows the corallites in perfect lateral union.

Finally the diagnosis of De Fromentel was altered by Mr. Tomes, and it will be noticed in the 'Essay on the Lower-Oolite Madreporaria,' p. 425, that *Chorisastrœa* has corallites "not divided by walls, gemmation is basal, the corallum lobular, the lobes springing from the base of the parent corallite."

These different diagnoses for one genus indicate that it has been attempted to be founded on the methods of growth of structures which are common to diverse genera and even families.

Following Milne-Edwards and Reuss, I restore the species included in the genus *Chorisastrœa* to their former position in the genus *Thecosmilia*, and persist in declining to introduce into the classification a genus which has three different diagnoses.

At the close of the essay now in course of consideration its author changes the name of *Thecosmilia obtusa*, d'Orb., to *Chorisastrœa obtusa*. The species was illustrated in my 'Monograph,' Pal. Soc. pt. iii. 1872, pl. i. figs. 1-4, and it will be perceived that the increase is by fissiparity, and that there is no deep groove between the walls of the primary and secondary calices. There is nothing *Chorisastrœan* about the form, according to the generic definition of M. de Fromentel, and I therefore restore the species to the genus *Thecosmilia*.

Genus HETEROGYRA, Reuss.

The comparatively circular corallites free at the margin, and the increase both by gemmation and by irregular serial growth, distinguish this genus from its close ally *Latimæandra*. It differs from *Chorisastræa*, as shown in the definition given by its founder.

Genus SYMPHYLLIA, Ed. & H.

After due consideration and careful examination of the recent species of *Symphyllia*, I restore *Symphyllia Etheridgei*, nobis, which had been removed to a new genus, *Phyllogyra*, by Mr. Tomes. It is usual, when a naturalist alters the generic position of a species, that a reason should be given; this was not done by Mr. Tomes, who created a genus to include the *Symphyllia* just alluded to.

No comparison of the new genus *Phyllogyra*, Tomes, with *Symphyllia* was instituted, and yet a little study of the figures given (pl. vi. figs. 6 and 7, Pal. Soc. 1872, Monogr. Brit. Foss. Corals, pt. iii.), and their comparison with calices of recent *Symphylliæ*, will show that the fossil and recent species are generically allied. This subject has been considered in the "Revision of the Genera," p. 92, and although I had grave doubts about the genus *Phyllogyra*, Tomes, I placed it in the classification. But I differ from the author of the genus in believing that the calices he thinks came from gemmation are the result of fissiparity. The genus is not synonymous with *Symphyllia*. It is very interesting to note the similarity of the figure given of the base of *Phyllogyra*, Tomes, *op. cit.* pl. xviii. fig. 5, and that of *Phylloseris rugosa*, Tomes, fig. 8 of the same plate.

Thecoseris polymorpha, Tomes, was described in the Geological Magazine; but, although it is figured in the essay on the Madreporaria of the Lower Oolite (pl. xviii. figs. 12, 13), no description of the species is given in the text. This is to be regretted, because the genus cannot have any alliance with the Australian form which I described some years since, or with a well-known Lower Cretaceous and Tertiary genus named by me *Turbinoseris*. Mr. Tomes clearly would have *Turbinoseris* and *Palæoseris*, nobis, made synonymous with *Thecoseris*, E. de From. But the anatomy of the series of forms shows marked distinctions between the genera. As a matter of fact, Pratz has shown that *Leptophyllia*, Reuss, is a Fungid with perforate septa, and *Haplaræa*, Milasch., is synonymous. Now *Thecoseris* only differs from *Leptophyllia* in having a strong epitheca, a subgeneric attribute. Thus *Thecoseris* is a subgenus, and may or may not be used according to the value palæontologists put on subgenera, and it is long after *Leptophyllia* in date of publication. *Turbinoseris* has solid septa and belongs to a different family of the Fungida from *Leptophyllia* and *Thecoseris*. In the "Revision of the Genera" I have shown that it is associated with *Trochoseris* and other allied genera. *Palæoseris* I have reduced to the position of a subgenus; its distinction from *Turbinoseris* is subgeneric.

Thecoseris polymorpha, Tomes, should remain where its author placed it, but only as a subgenus of *Leptophyllia*, Reuss. The form

has no alliance with *Turbinoseris* and *Palæoseris*, nobis, as Mr. Tomes supposes.

The next communication to which I have to direct attention is "On the Fossil Madreporaria of the Great Oolite of the counties of Gloucester and Oxford," by R. F. Tomes, Esq., F.G.S., Quart. Journ. Geol. Soc. vol. xxxix. 1883, p. 168. This communication contains some very interesting and valuable stratigraphical data, and speaks well for the author's industry. He assigns the species often to definite horizons, and adds several very interesting forms to the fauna. But there are criticisms of the work of previous observers in it, and especially of Milne-Edwards and Jules Haime and myself, which require answering.

The confusion into which Mr. Tomes has thrown the group of species which Milne-Edwards and Jules Haime placed within the genus *Cyathophora* of Michelin, is added to by his giving new generic diagnoses to this genus and to *Cryptocænia* *. He first of all states that the genera *Cyathophora* and *Cryptocænia* are of d'Orbigny's proposition, forgetting that the first was not d'Orbigny's, and that it was chosen from Michelin's work by Milne-Edwards and Jules Haime to supersede *Cryptocænia* of d'Orbigny, the definition of which was not sufficiently exact to be worth anything. Next, very properly, seeing the impossibility of retaining the two genera according to De Fromentel's classification, he says, the genera, "in my opinion, require some modification," which he gives as follows (*op. cit.* p. 194):—" *Cyathophora*. Cœnenchyma small in quantity and dense. Gemmation proceeding from it in close proximity to the walls of the corallites, if not actually from the walls themselves. Septa feebly developed, and the cycles not traceable. Calices generally much crowded, appearing at many heights, often oblique, oval, or even polygonal." Now this is not a modification, for it is a diagnosis totally unlike that of Michelin. Not a word is said about the tabulæ which were noticed by Milne-Edwards; but it is to be inferred that they are recognized, for the genus is separated in the classification from *Cryptocænia* by Mr. Tomes, and is placed in the family Thecostegitæ of De From., and amongst the Tabulata. Then, on the next page, we read, "It is with very great doubt that I have given this species (*Cyathophora Bourgueti*) a place in the Zoantharia Tabulata, not having, by any means, satisfied myself as to its real affinities." Yet this species is the only one of the genus, according to Mr. Tomes, which is in the British Oolitic fauna.

* *Cryptocænia* was thus diagnosed by d'Orbigny:—

"A *Tremacænia* without a styliform columella."

C. bacciformis was the type. There was great doubt whether the form was not a true *Stylina* the columella of which had fallen out by wear and weather.

Tremacænia was dropped and it is now *Stylina*.

The diagnosis of *Cryptocænia* was insufficient, and Milne-Edwards and Jules Haime, finding a remarkable arrangement of the endotheca in certain corals which otherwise would have been considered to be *Stylina* without columellæ, associated the species with the genus *Cyathophora* of Michelin.

The imperfect tabulæ of *Cyathophora* fill up the visceral cavity to a considerable extent, and it is evident that the columella is wanting in the types.

Cryptocœnia is thus modified by the same hand:—"Cœnenchyma abundant and of a loose nature, composed of a great many dissepimental tabulæ, from which the gemmation takes place quite distinct from the walls of the corallites. Septa well developed, and their cycles distinct. The calices not crowded, always round and on the same level." This is a new definition altogether. Now, although the presence of tabulæ is asserted in this genus, the forms are not placed in the Tabulata by Mr. Tomes, as are the species of *Cyathophora*. To those palæontologists who have not studied the Corals these definitions may appear to be very distinctive; but such is not the case. The amount of cœnenchyma in these forms is a matter of growth; the cyclical arrangement of the septa and their length are clear in some forms; but no one can doubt that the condition of the septa in the miserable specimens of the form named *C. Bourgueti*, so miserable that Mr. Tomes confesses that he cannot make out the real affinities, is due to weather and fossilization. The cyclical arrangement of the worn-down septa, which look like mere ridges on the inside of the wall, can be made out by the septal number and by the costæ.

The gemmation is, in all the forms, extra-calicular, and that is an important point, for it is perfectly well known that in *Stylina* the gemmation is always extra-calicular, and is usually from the intermural space, or, it may be, from the wall outside the calice. The crowding or the reverse of the calices is also a matter of individual growth, and is not generic.

Notwithstanding the indifferent structural details of the form *Bourgueti*, Mr. Tomes asserts its identity with the species described by Michelin, and therefore relegates all the species which Milne-Edwards described as belonging to *Cyathophora*, Michelin, to the old genus *Cryptocœnia*. Mr. Tomes altered the generic titles of the species described by myself as *Cyathophoræ*, but he was not quite sure that he was right, and he writes as follows:—"But if, on the other hand, it [*Cyathophora Bourgueti*] should eventually prove to differ from *Cyathophora* generically, then the genus *Cryptocœnia* must be dropped, and a new genus formed to receive the present species; for this *Depaphyllum* would not be an inappropriate name." *Cryptocœnia* thus stands on a very slight foundation.

The fact is, that neither of the genera enlarged upon by Mr. Tomes belongs to the Tabulata; that Milne-Edwards and Jules Haime were correct in associating certain *Cryptocœnia* with *Cyathophora*, Mich.; and that the distinctions attempted to be drawn between *Cyathophora*, as elaborated by the authors just mentioned, and the ill-defined genus *Cryptocœnia*, d'Orb., are insufficient, and are founded upon the observation of bad specimens.

In concluding this reference to the impropriety of altering the generic names of the *Cyathophoræ* given by Milne-Edwards and myself in the 'British Fossil Corals,' it is necessary to mention that *Cryptocœnia microphylla*, Tomes, of which a figure is given (Quart. Journ. Geol. Soc. vol. xxxix. pl. vii. fig. 2), has all the specific characters of *Cyathophora tuberosa*, nobis, except that this last is a

larger form. The cycle of costæ without septa and the small second cycle of septa are common to both forms. In Mr. Tomes's species there are gibbosity and dome-shaped prominences of the massive coral; and it is evident that those conditions bring the form, the septa and costæ being the same, within my species *Cyathophora tuberosa* as a well-marked variety.

Cyathophora tuberosa, nobis, will retain its generic title. Mr. Tomes states that this species bears so close a resemblance to *C. luciensis*, Ed. and H., that it may probably prove to be identical with it. The distinction is evident, and consists in the absence of the third cycle of septa in *C. tuberosa*; the tuberosa form is also specific, as is likewise the distance between the decidedly raised calices.

Cyathophora Pratti, Ed. and H., was not at first appreciated by Mr. Tomes; for he referred some corals to it, according to his own statement (*op. cit.* p. 179), erroneously.

MONTLIVALTIA CARYOPHYLLATA, Lmx.

Mr. Tomes makes the following remark (*op. cit.* p. 180):—"There is an *obvious error* in the description given of this coral by MM. Milne-Edwards and Haime (*Hist. Nat. des Corall.* t. xi. p. 303). The number of cycles given by them is five and *part of a sixth*. This statement, however, has been corrected by M. de Fromentel, who says, there are in a large calice as many as 162 visible septa. In the calices of those I have examined there are about 108 septa." Here the reference to the obvious error ends, and we are not directly informed what it was; but the inference left to be drawn is, that corals *having either 162 or 108 septa have not five cycles and part of a sixth*. Now in looking over M. de Fromentel's works, I find, in his 'Introduction,' p. 117, and also in the *Paléontologie Française* (*Terr. Jurass. Zooph.* p. 202), that the coral has "cinq cycles et rarement des cloissons d'un sixième." The number 162 is mentioned as occurring in a large calice.

It does not appear, then, that M. de Fromentel corrected an obvious error; for the number of 108 septa means five cycles (96 septa) and a part of the sixth cycle, that is to say five cycles and one eighth of a sixth. M. de Fromentel's number of 162 septa means five cycles and just over five eighths of a sixth cycle. MM. Milne-Edwards and Haime were quite correct in giving the form the septal arrangement of five cycles and part of a sixth.

In the communication under consideration the credit is given to M. de Fromentel of drawing attention to the necessity of distinguishing between fissiparity and gemmation; and it is mentioned that this author states that the corallite which is the result of fissiparity is not enclosed in a *new and distinct wall*, even when it has become separated from the parent calice!

Now Pallas, in 1766, drew attention to the fissiparity of corals, and Ehrenberg, in 1834, made fissiparity, which he thoroughly under-

stood, one of the fundamental bases of his classification Dana drew splendid examples, and the whole subject was elaborately discussed by Milne-Edwards and Jules Haime in the first volume of their *Hist. Nat. des Corall.* pp. 74-83.

The illustrations I gave of fissiparity in the "Monograph of the British Fossil Corals," 2nd Ser. Pal. Soc. 1866, p. 23, and in the earlier plates were copies from the admirable work of Milne-Edwards and Jules Haime. M. de Fromentel was merely the copyist of his predecessors. After reading M. de Fromentel's description of fissiparity, I fail to find the sentence which states that the walls are defective, as stated by Mr. Tomes. M. de Fromentel states just the contrary, and explains how the walls of the fissiparous calices may unite with their neighbours and produce polygonal calices. He says, "Bientôt les murailles se reserrent entre les deux centres, qui s'écartent, s'éloignent peu à peu et deviennent complètement indépendants" (p. 41). It would be indeed remarkable to find distinct corallites, the result of evident fissiparity, without walls!

These remarks on the subject of fissiparity are necessary because the particular opinions of Mr. Tomes are utilized in a criticism of MM. Milne-Edwards and his confrère and myself in regard to the fissiparity of *Thecosmilia gregaria*, McCoy, sp. Mr. Tomes (p. 168) states that fissiparity and gemmation are sometimes confounded, and proceeds, "Thus the usually accurate observation of MM. Milne-Edwards and Haime failed in the so-called *Thecosmilia gregaria* to distinguish between them; and the error of supposing this species increased by division was continued by Prof. Duncan and myself."

Mr. Tomes withdraws from the company in which he once found himself, and insists that this well-known and most variable species only increases by gemmation.

I have seen fissiparity, and so did Milne-Edwards and Haime; and it may be observed in the upper part of Mr. Tomes's own figure (*Quart. Journ. Geol. Soc.* vol. xxxviii. pl. xviii. fig. 3).

It is necessary to object to the species *Thecosmilia Slatterii*, Tomes (p. 182). The author of it remarks, "This is a small and well-marked species, having much the appearance of *Cladophyllia Babeana*, Ed. and H." As the form has a resemblance to a different genus from that in which it is included, the possibility of its being a well-marked one does not exist. At the close of his description of the species its author remarks:—"I entertain little doubt that the present species was figured by Prof. Duncan in his 'Supplement to the British Fossil Corals' as a variety of *Cladophyllia Babeana*." There need be no doubt upon the point; all the details of the figures given by me many years ago coincide with the description of the form by Mr. Tomes. *Cladophyllia* is really a subgenus of *Thecosmilia*, and *Thecosmilia Slatterii*, Tomes, is a variety of *Thecosmilia (Cladophyllia) Babeana*, Ed. and H.

In concluding my remarks on the criticisms contained in the essay on the Madreporaria of the Great Oolite, it is necessary to allude to the use of the word geniculate again. I found a specimen

of *Thamnastræa Waltoni*, Ed. and H., and had it figured (Pal. Soc. pt. iii. pl. xi. figs. 6-9). Mr. Tomes says:—"The figures given by Dr. Duncan as of this species, but unaccompanied by letterpress, must, in my opinion, be referred to some other species which has the septa more strongly geniculated." In other words the geniculate condition of the form is greater than in the true type of *Thamnastræa Waltoni*. Now on looking at the figures, it will be noticed that there is very slight geniculation—it could hardly be slighter. It was this want instead of excess that made me doubt for a while about the identity of the form and the species *Waltoni*.

Mr. Tomes communicated to the Society his essay "On some imperfectly known Madreporaria from the Coral Rag and Portland Oolite of the Counties of Wilts, Oxford, Cambridge, and York" in 1883 (Quart. Journ. Geol. Soc. vol. xxxix. p. 555).

It is very satisfactory to be able to agree with the author in most of the descriptions and opinions given and expressed in this communication; nevertheless there are some points on which there is considerable difference between us.

It is to be noticed with some satisfaction that the genus *Thamnastræa* is partly taken out of the Perforata and restored to the Fungidæ. But it is to be gleaned that the author still inclines to place the species with perforate septa in the section Perforata. It is proposed to separate the perforate and imperforate *Thamnastræans* into different genera; but the answer to this proposition may be gleaned from what has already been written elsewhere. In some *Thamnastræans* the septa are perforate, thanks to fossilization, in all their laminae; in others of the same species only parts of the corallum have their septa perforate, the rest being imperforate. The same species will be found under different circumstances to present perforate and imperforate septa. Unless we are to have the novelty of two genera in one individual the proposition of dividing the *Thamnastræans* must drop.

The figures given by Mr. Tomes on plate xxii. of *T. concinna*, Goldf., sp., are very remarkable, and they explain why the author stated, "These often exhibit forms so remarkable as to suggest specific or almost generic distinction, and they deserve especial notice" (p. 559).

They really present so many resemblances to a *Stylina* and so few to *Thamnastræa concinna* that it is to be hoped careful sections will be placed where they can be studied.

ISASTRÆA OBLONGA, Ed. and H.

The distinguished authors of the 'British Fossil Corals' are said to have overlooked the real characters of this species. They were misled by the state of fossilization. The following is the statement of Mr. Tomes (p. 563):—"By selecting specimens in which the silicified corallites are less deep in colour the details of structure are more readily seen, and the wall is observed to be thin and to be lined within with a considerable quantity of dissepi-

mental tissue, through which the septa pass and from which they are clearly distinguishable. This tissue assumes a concentric arrangement, something like a series of rudimentary walls, one within the other, as in *Lithostrotion*, in which genus it was first placed by its first describer. Sometimes the inner ring of endotheca is more fully developed than the others, simulating an inner wall; but this is not constantly the case, or it would furnish grounds for the creation of a new genus." But Mr. Tomes had not read carefully the description of the species in the 'British Fossil Corals' and in the *Hist. Nat. des Corall.* vol. ii. p. 529 by Milne-Edwards and Jules Haime. In the first-mentioned work is stated, "The dissepiments, which in many specimens have disappeared completely or have been more or less modified in form by fossilization, are well developed, arched, somewhat decline inwards, and situated at one third or one fourth of a line apart; some remain simple, but most of them bifurcate" (p. 74). "Traverses bien développées, arquées, un peu inclinées, ordinairement bifurquées" (*Hist. Nat. des Coral.* p. 529).

The description of the endotheca by Milne-Edwards and Haime was correct and quite sufficient for the purpose of specific distinction. The notion of there being a set of walls one within the other is not correct, and the appearance is due to the obliquity of the dissepiments and their being cut across horizontally in making sections.

The author states (p. 558) that "increase takes place in this species by gemmation on the walls between the calices, just as in *Isastræa*." The gemmation of *Isastræa* certainly does not take place between the walls of corallites, but within the calicular margin; it is between the margin and the centre of a calice.

It is also necessary to draw attention to the figure given by Mr. Tomes of *Isastræa oblonga*, in which there is a very decided columella. It is the result of fossilization, and is similar in cause to that seen in *Astrocœnia major*, Tomes, which is probably a *Thamnastrea*, for it has synapticulæ.

"On some new or imperfectly known Madreporaria from the Great Oolite of the counties of Oxford, Gloucester, and Somerset. By R. F. Tomes, Esq., F.G.S. (*Quart. Journ. Geol. Soc.* vol. xli. p. 170, 1885)."

A few remarks are necessary on my part upon some criticisms of the previous work of MM. Milne-Edwards and Jules Haime and myself.

Mr. Tomes heads a paragraph with the name *Heliocœnia*, makes it a synonym of *Placocœnia*, d'Orbigny, and gives a good notion of the discrepancies of opinion regarding the value of the genera. Milne-Edwards, Jules Haime, M. de Fromentel, and myself do not recognize the genus *Heliocœnia*, Etallon; d'Orbigny founded *Placocœnia*, M. Koby associated *Heliocœnia* and *Stylohelia*. Mr. Tomes differs from all these naturalists and retains *Heliocœnia* without giving any reason. In fact, if the reason for associating

this so-called genus with *Stylina* were given, the identity of the two must be conceded.

The only distinction between the two genera is, that in *Heliocœnia* the costæ do not extend far from the septal margin. The compression of the columella is not invariable, and it is of no physiological importance. In specimens of recognized *Stylina*, parts may often be found with the characters of *Heliocœnia*. I agree with the great French zoophytologists to a certain extent, and without abolishing the group, I have reduced it to the rank of a subgenus. But no *Heliocœnia* has a lamellar columella, as drawn by the author of the paper under consideration (plate v. fig. 17).

Placocœnia, which Mr. Tomes considers to be synonymous with *Heliocœnia*, is a much better-marked genus than he thinks. He is not justified in saying that d'Orbigny's genus is not sufficiently particularized for adoption. *Placocœnia*, as illustrated by Goldfuss and described by d'Orbigny, is well characterized as follows:—Colony massive. Calices large, circular or oval, rather distant, united by costæ. Columella lamellar and well developed, or in three papillæ. Septa entire, unequal, of decamerall or of hexamerall type. Costæ thick and well developed, cristiform or granular. Gemmation between the calices. ("Revision of the Genera," p. 108.)

The distinctions between *Stylina* (= *Heliocœnia*) and *Placocœnia* are obvious.

Mr. Tomes does not see any alliance whatever between the genus *Stylolohelia* and the Oculinidæ, and has no hesitation in removing it into the neighbourhood of *Stylina*. He gives no reason; but that given in the "Revision" can be gleaned by reading the descriptions of the recent genera with which it is associated, namely *Stylophora* and *Madracis*. It is hard to believe that the figures given by Mr. Tomes on his plate v. figs. 15–17, are from the same specimen or that they are correct. One calice has a lamellar columella and few septa, and the other has no columella and numerous septa, and is said to be the younger of the two. The arrangement of the costæ differs also.

ISASTRÆA CONYBEARII, Ed. & H.

This species was described and figured by Milne-Edwards and Jules Haime in their monograph of the British Fossil Corals, Pal. Soc. pl. xxii. fig. 4.

It is a form with large tetragonal calices and a septal number unusually small in relation to the size of the calices. It is characterized as follows:—"Calices nearly equal, subtetragonal and circumscribed by a simple edge common to the two adjoining corallites or separated by a slight furrow. Long diameter of the calices 6 or 7 lines. No columella." The figure shows the usual sharp edge to the calices, and that the septa have no costal prolongations. The junction of one or two septa in the axis was not considered sufficient to be called a columella.

This species is now stated by Mr. Tomes not to be an Isastræan but to be the same as a form which was placed in a totally different

genus by Milne-Edwards and Jules Haime, namely *Clausastræa*, the form being *C. Pratti* (now *Plerastræa Pratti*, Ed. & H.). This species was figured on the same plate as *Isastræa Conybearii* by Milne-Edwards and Jules Haime. The only defective part of the drawing of *Clausastræa Pratti*, which was afterwards placed in the genus *Plerastræa*, is owing to the bad printing. The print gives the notion of a solid columella, and this is not correct. In the context it is stated that the columella is spongiöse and well developed. The part of the coral towards the left hand of the observer in the plate (this was not reversed by the artist) shows most distinctly that there are long wavy and geniculate septo-costæ. They are in groups, as it were. The type specimen is in the Museum of the Geological Society, and its faithful resemblance to the figure given on plate xxii. of the monograph of Milne-Edwards and Jules Haime of 'Corals from the Great Oolite,' is very remarkable. It is correct in every respect except in the indifferent printing of the very distinct columellæ, which are formed by the septal ends and also by some additional tissue. The description of the species agrees with the drawing and with the type.

Mr. Tomes writes, p. 184, "All the specimens recently collected at Combe Down may be referred either to *Clausastræa Pratti* or to *Isastræa Conybearii*, according to the condition of the specimen examined.

In disputes of this kind we must take the type specimen for the purpose of comparison; and then it is perfectly evident that the two species mentioned above, and which were described and figured by Milne-Edwards and Jules Haime, are generically distinct. The long and often geniculate costæ which unite the septa of somewhat distant calices in one species are totally opposed to the diagnosis of an *Isastræan*. *Isastræa Conybearii* has, from the description and figure, all the characters of an *Isastræan*, and such septo-costæ as exist in the other form could not by any possibility be produced by weathering.

There is merely a slight union of a thinning-out septum in the axial space of the *Isastræan* with one or more of its fellows; but in the type of the other species there is thickening of the septal ends, and the axial space is as it is in recent corals which have columellæ made up by the inner ends of the septa, more or less additional tissue being added. Such a columella is a parietal one, and when well preserved in recent and fossil forms often exhibits papillæ at the free surface.

It is to be noticed that Mr. Tomes persists in placing the species of coral with a columella and geniculate and more or less grouped septo-costæ in the genus *Clausastræa*, in spite of Milne-Edwards and Jules Haime having removed it from that genus 28 years since. They placed the form as a species of *Plerastræa*. He writes (p. 183):—"Under the impression that the so-called *Clausastræa Pratti* has an essential columella, the original describers transferred it to the genus *Plerastræa*, in which genus it appears in their general work on corals.

“But from the examination of a number of specimens from Combe Down, I am convinced that the supposed columella does not exist in any of them.”

Now there is nothing written about an essential columella in the diagnosis of the genus *Plerastræa* by its founders. Such a columella arises from the base of the coral within and grows irrespectively of any other structures, and the styloid columellæ of *Stylina* are excellent instances. The columella in the form which first of all came under the designation of *Plerastræa*, *P. Savignyi*, Ed. & H., has the “columelle papilleuse représentée par des pointes du bord interne des cloissons” (Hist. Nat. des Corall. p. 553, v. 2). Hence in the diagnosis it is stated that the columella is “papilleuse.”

As it was evident to Milne-Edwards and Jules Haime that *Plerastræa Pratti*, formerly called by them *Clausastræa Pratti*, had a fasciculate columella of the Plerastræan type, and as it is to be seen in their type specimen, any comparison of the form with one without a columella is necessarily misleading. Mr. Tomes states that the type was a worn specimen; but had he seen it (unfortunately he has not) he would have been able to bear out the correctness of the description in the monograph of the British Fossil Corals. It is, then, necessary to restore *Isastræa Conybearii*, Ed. & H., and *Plerastræa Pratti*, Ed. & H., to their former positions, and the union in a new genus *Platastræa* is not requisite.

Genus BATHYCCENIA, Tomes.

In the essay “On some imperfectly known Madreporaria from the Great Oolite,” p. 176, Mr. Tomes writes as follows:—“Great doubt is expressed by Prof. Duncan, in his ‘Revision of the Families and Genera of Corals,’ as to the distinctness of *Bathyccenia* from *Stylosmilæa*, which genus, in habit of growth, it somewhat resembles.” He then proceeds to state that he had made careful comparison of well-preserved specimens of Tertiary *Stylosmilæa* with *Bathyccenia*, and that the absence of a true columella was clearly made out. Now on turning to the “Revision of the Genera,” p. 122, it will be noticed that no doubts whatever were expressed about the distinctness of *Bathyccenia* and *Stylosmilæa*. The name of the last genus is not even mentioned, and what was written in respect of the resemblances of *Bathyccenia* with another genus, was copied from Mr. Tomes’s own statements in his paper on the “Great Oolite Madreporaria,” 1883, p. 176. He there compared the genus with two Tertiary species of the same genus, *Stylocenia*, which I mentioned in the “Revision.”

At that time (Tomes, *op. cit.* p. 176) the genus *Bathyccenia* had a “rugged columella;” at the present time Mr. Tomes asserts that it has none, in spite of the figures 8, 9, 10, pl. vii. of his work, where the structure is well seen.

The genus *Stylosmilæa* is not known in the Tertiary strata.

Nomenclature of Species.

<i>Astrocœnia costata</i> , <i>Dunc.</i>	is not <i>Stylastrœa sinemuriensis</i> , ^{no} <i>E. de F.</i>
— <i>superba</i> , <i>Dunc.</i>	” — <i>Martini</i> , <i>E. de F.</i>
— <i>plana</i> , <i>Dunc.</i>	” — <i>plana</i> , <i>Dunc.</i> , sp.
— <i>gibbosa</i> , <i>Dunc.</i>	” — <i>gibbosa</i> , <i>Dunc.</i> , sp.
— <i>reptans</i> , <i>Dunc.</i>	” — <i>reptans</i> , <i>Dunc.</i> , sp.
— <i>parasitica</i> , <i>Dunc.</i>	” — <i>parasitica</i> , <i>Dunc.</i> , sp.
— <i>pedunculata</i> , <i>Dunc.</i>	” — <i>pedunculata</i> , <i>Dunc.</i> , sp.
— <i>dendroidea</i> , <i>Dunc.</i>	” — <i>dendroidea</i> , <i>Dunc.</i> , sp.
— <i>minuta</i> , <i>Dunc.</i>	” — <i>minuta</i> , <i>Dunc.</i> , sp.
— <i>favoidea</i> , <i>Dunc.</i>	” — <i>favoidea</i> , <i>Dunc.</i> , sp.
<i>Cyathocœnia incrustans</i> , <i>Dunc.</i>	” <i>Phyllocœnia incrustans</i> , <i>Dunc.</i> , sp.
— <i>dendroidea</i> , <i>Dunc.</i>	” — <i>dendroidea</i> , <i>Dunc.</i> , sp.
— <i>costata</i> , <i>Dunc.</i>	” — <i>costata</i> , <i>Dunc.</i> , sp.
<i>Phyllocœnia decipiens</i> , <i>Laube.</i>	” <i>Cyathocœnia decipiens</i> , <i>Laube</i> , sp.
<i>Thecosmilia serialis</i> , <i>Dunc.</i>	” <i>Elysastrœa serialis</i> , <i>Dunc.</i> , sp.
<i>Elysastrœa Moorei</i> , <i>Dunc.</i>	” — <i>Fischeri</i> , <i>Laube.</i>
<i>Circophyllia</i> (<i>Antillia</i>) <i>oolitica</i> , <i>Tomes</i> , sp.	” <i>Cyathophyllia oolitica</i> , <i>Tomes.</i>
<i>Montlivaltia</i> (<i>Oppelismilia</i>) <i>Holli</i> , <i>Dunc.</i>	” <i>Donacosmilia Holli</i> , <i>Dunc.</i> , sp.
— <i>pedunculata</i> , <i>Dunc.</i>	” <i>Cladophyllia subdichotoma</i> , <i>Laube.</i>
— <i>polymorpha</i> , <i>Terquem et Piette</i>	” <i>Thecosmilia major</i> , <i>Terq.</i>
— <i>Haimei</i> , <i>Ch. et Dew.</i>	” <i>Montlivaltia rhætica</i> , <i>Tomes.</i>
<i>Axosmilia Wrighti</i> , <i>Ed. & H.</i>	” <i>Donacosmilia Wrighti</i> , <i>E. & H.</i> , sp.
<i>Clausastrœa consobrina</i> , <i>Ed. & H.</i>	” <i>Confusastrœa = Adelastrœa con-</i> <i>sobrina</i> , <i>Ed. & H.</i>
<i>Isastrœa tenuistriata.</i>	” — <i>tenuistriata.</i>
<i>Thecosmilia gregaria</i> , <i>M' Coy.</i> sp.	” <i>Chorisastrœa gregaria</i> , <i>M' Coy.</i> , sp.
— <i>obtusa</i> , <i>Dunc.</i>	” — <i>obtusa</i> , <i>Dunc.</i> , sp.
— (<i>Cladophyllia</i>) <i>Babeana</i> , <i>Ed. & H.</i> , var. =	<i>Thecosmilia Slatteri</i> , <i>Tomes.</i>
<i>Isastrœa Conybearii</i> , <i>Ed. & H.</i>	is not { <i>Platastrœa Conybearii</i> , <i>Ed. & H.</i> , sp.
<i>Plerastrœa Pratti</i> , <i>Ed. & H.</i>	” — <i>Pratti</i> , <i>Ed. & H.</i> , sp.
<i>Symphyllia Etheridgi</i> , <i>Dunc.</i>	” <i>Isastrœa Conybearii</i> , <i>Ed. & H.</i>
<i>Cyathophora tuberosa</i> , <i>Dunc.</i>	” <i>Phyllogyra Etheridgei</i> , <i>Dunc.</i> , sp.
”	” { <i>Cryptocœnia tuberosa</i> , <i>Dunc.</i> , sp.
”	” — <i>luciensis</i> , <i>Ed. & H.</i>
”	” — <i>microphylla</i> , <i>Tomes.</i>
<i>Leptophyllia polymorpha</i> , <i>Tomes</i> , sp.	= <i>Thecoseris polymorpha</i> , <i>Tomes.</i>
<i>Dimorpharœa Lycetti</i> , <i>Dunc.</i> , sp.	= { <i>Cyclolites Lycetti</i> , <i>Dunc.</i>
	= { <i>Dimorphastrœa dubia</i> , <i>Tomes.</i>

SUMMARY.

All the species of the genus *Astrocœnia* which were described in the 'Supplement to the British Fossil Corals,' Pal. Soc. 1867, from the Infra-Lias of South Wales belong to that genus, and not to *Stylastrœa*, De From. The drawing of *Astrocœnia plana*, nob., given by Mr. Tomes, does not correspond with the type specimen of the species. *Stylastrœa sinemuriensis* and *S. Martini*, De From., do not form part of the fauna of the Infra-Lias of South Wales. *Cyathocœnia*, nob., is not the same as *Phyllocœnia*, Laube, which is *Koilocœnia*, nob. The St.-Cassian *Phyllocœnia decipiens*, Laube, is

Koilocœnia decipiens, Laube, sp.; but it is not found in England. *Theocosmia Martini* and *T. Michelini* of the European Hettangian, are found in the Infra-Lias of England. *T. rugosa*, Laube, was first noticed in the "Memoir of the Corals of the Zone of *Ammonites angulatus*," Pal. Soc. 1867, and the species was properly figured. *T. serialis*, nob., is correctly named. *T. Horneri*, Laube, has not yet been shown to belong to the British Infra-Lias, neither has *T. confluens*, Laube. *Cladophyllia* is a subgenus of *Theocosmia*. *Elysastrœa*, Laube, has two well-marked species in the Sutton Stone. *Montlivaltia simplex* has the shape of the calice not merely dependent on pressure, but caused by normal growth. *M. Walliæ*, nob., has no evidence of "rejuvenescence," and the growth noticed is endothecal, and would be termed by Lindström stereoplasm. *M. polymorpha*, Terquem et Piette, remains a member of the Infra-Lias fauna. *M. pedunculata*, nob., is not a *Cladophyllia*, but a simple coral of the genus to which it was first assigned. The geological position of the Sutton Stone and associated deposits is, from the palæontological evidence, above the Rhætic Series.

The cast of a *Montlivaltia* figured in the "Memoir on the Corals of the Zone of *A. angulatus*," Pal. Soc. 1808, p. 68, does not coincide with *M. rhætica*, Tomes, but with the form with which it was associated by me, namely *M. Haimeii*. *Montlivaltia foliacea*, Tomes, has not nine cycles of septa as stated by its describer. The septal arrangement of *M. excavata*, Tomes, and *M. papyracea*, Tomes, is doubtful. *Thamnastrœa* is not a perforate Coral, but a Fungid. *Synastrœa* and *Centrastrœa* were not founded by M. de Fromentel; the first originated with Milne-Edwards, and the second with d'Orbigny. *Centrastrœa* is not synonymous with *Astrœomorpha*, as proved by Reuss and E. Pratz. *Oroseris* is not a perforate Coral; and Milne-Edwards and Jules Haime were quite correct in stating that the genus "se rapproche beaucoup des *Comoseris*," and it is incorrect to state that one genus really bears only a faint resemblance to the other. *Oroseris* is a subgenus of *Comoseris*, which, of course, is not one of the Perforata. *Microsolena*, Lmx., is one of the Fungida.

Cyathophyllia, E. de From., is subsequent in date to *Antillia*, nob.; and therefore *C. oolitica*, Tomes, is *Antillia oolitica*, Tomes, sp.; but, as I now place *Antillia* as a subgenus of *Circophyllia*, Ed. and H., the term should be *Circophyllia oolitica*, Tomes, sp., providing that the form is not one of the Fungidæ, to which group it has a close resemblance.

What is termed the "rejuvenescence" of corals by some palæozoophytologists has been long recognized as irregularity of growth; and there should be no difficulty in distinguishing worn growth-rings from calicular gemination; but this has been confounded with the other condition. *Oppelismilia*, nob., is retained as a subgenus of *Montlivaltia*. *Axosmia Wrighti*, Ed. & H., and *Montlivaltia (Oppelismilia) Holli*, nob., are not identical; they are both simple corals and differ from the fasciculate and compound genus *Donacosmia*, E. de From. *Epismilia* is a worthless genus. *Clausastrœa conso-*

brina, Ed. & H., is not a species of *Confusastræa*. *Isastræa tenuistriata*, McCoy, sp., confounded with some other form, but not by its author, is a true *Isastræan*. *Confusastræa tenuistriata* Tomes, cannot remain in that genus; for it has characters which do not belong to it. *Chorisastræa*, De From., is not a good genus. *Thecosmilia gregaria* and *T. obtusa* are names which should be retained, and the forms should be removed from *Chorisastræa*. *Heterogyra*, Reuss, is a good genus. *Symphyllia Etheridgei*, nob., belongs to the genus with which it is associated, and not to *Phyllogyra*, Tomes. *Thecoseris* is an epithecate *Leptophyllia*; and *T. polymorpha*, Tomes, is quite distinct in its morphology from *Turbinoseris* and *Palæoseris*, nob. *Cryptocænia*, d'Orb., is an imperfectly distinguished genus, and is replaced by *Cyathophora*, Ed. & H. Therefore *Cyathophora tuberosa*, nob., which has not a close resemblance to *C. luciensis*, Ed. & H., and also *C. Pratti*, Ed. & H., remain as good species of their genus. *Cryptocænia microphylla*, Tomes, is a variety of *Cyathophora tuberosa*, nobis. *Montivaltia caryophyllata*, Ed. & H., had not its septa wrongly described by its authors. Fissiparity and gemmation were not confounded by Milne-Edwards and J. Haime, or by myself. *Thecosmilia Slatteri*, Tomes, is a variety of *Cladophyllia Babeana*, Ed. & H. The figure given by me of *Thamnastræa Waltoni*, Ed. & H., has been misapprehended.

Isastræa oblonga, Ed. & H., was correctly described by the authors, and no addition to the knowledge of the form has been made. The genus *Isastræa* has its species budding within the calice and close to the outer wall, never, as stated, between the walls of calices. *Heliocænia* is a subgenus of *Stylina*, has not a lamellar columella, and differs from *Placocænia*, d'Orb. *Isastræa Conybeari*, Ed. & H., is a good species; it is not the same as *Clausastræa* = *Plerastræa Pratti*, Ed. & H. The type specimen of *Plerastræa Pratti*, Ed. & H., has a columella; and the authors of the genus did not describe it as having an essential columella. The genus *Platastræa* does not include these forms. *Bathycænia*, Tomes: nothing was stated in the work called a "Revision of the Genera of Madreporia" about the similarity of the genus and *Stylosmilia*. This statement is difficult of explanation.

Every one of these numerous statements is made in opposition to the opinions of Mr. Tomes. Proper acknowledgment is made regarding the useful knowledge conveyed by Mr. Tomes about the localities of corals and the zones in which some occur.

The author of this communication agrees with Mr. Tomes on two points:—Mr. Tomes has shown that, owing to the matrix of *Cyclolites Lycetti*, nob., not being sufficiently removed, the form is his *Dimorphastræa dubia*, and that properly the generic term should be *Dimorpharæa*. Again, Mr. Tomes has raised much doubt in my mind where a species I had placed under the genus *Lepidophyllia* should be placed; probably it will have to come within *Donacosmilia*, as stated by Mr. Tomes; but *Donacosmilia* requires careful working out.

DISCUSSION.

Mr. ETHERIDGE thought, with the author, that it was impossible to mistake *Astroccenia* for *Stylastraea* or a coral with coenenchyma between the walls. It had been clearly shown that Mr. Tawney's correlation of the Sutton Stone with the St. Cassian or the Muschelkalk was based on a wrong identification of certain fossils. Mr. Etheridge had not seen any of the corals belonging to Mr. Tomes and commented upon by Dr. Duncan.

10. NOTE on some RECENT OPENINGS in the LIASSIC and OOLITIC ROCKS of FAWLER in OXFORDSHIRE, and on the ARRANGEMENT of those ROCKS near CHARLBURY. By F. A. BATHER, Esq., Scholar of New College, Oxford. Communicated by Prof. PRESTWICH, M.A., F.R.S., F.G.S. (Read December 2, 1885.)

[Abridged.]

THIS account was written to bring before the notice of practical geologists some new sections on the works of Messrs. Bolton and Partners, at Fawler. The district treated of lies in quarter-sheet 45 S.W. of the Survey Map, and was described by Prof. Hull in his accompanying memoir, 1859, to which nothing was added by Prof. Green in his memoir, 1864. Accurate description rather than speculation has been aimed at ; still, as some alteration seems necessary, its probable lines are suggested from personal examination of the neighbourhood. The Evenlode valley exposes Liassic rocks to about $\frac{3}{4}$ mile below Fawler, where Great Oolite is brought down by a fault. Since the locality is well known, I proceed to describe the sections in ascending order.

Section A, in the brickyard (about the position of the "2," in "g" at Fawler).

	ft. in.
Soil formed by decomposition of marlstone rock-bed, containing in its lower part fragments of the same.....	1 0
ε. Reddish-yellow loam, in alternating bands of more or less sandy or clayey nature ; a hard band at junction with marlstone rock-bed	11 0
ζ. Blue clay containing nodules of harder rock, and a few <i>Septaria</i> , visible for.....	20 0
But a boring has proved the existence of the same rock to a further depth of	100 0

The cores of the boring were not preserved ; they were, I am told, of the same character throughout. The line of junction of beds ε and ζ is 14 ft. above the bed of the river.

Section B, in a coombe across the road N.E. of the brickyard, clearly marked on the map by a branching-off of the Lias and Inferior Oolite into the Great Oolite plateau. A deserted opening extends S.W. by N.E., along the north side of this coombe for nearly 200 yards. The strata here are so variable in thickness that no definite section can be given. The lowest is marlstone rock-bed (δ), varying from 8 to 10 ft., but in one part so displaced that it appears in vertical section 12 ft. thick. At the west end of the pit it has a N.W. dip, *circa* 15°. Lying on the broken surface of this rock is a blue clay (Upper Lias, γ) with average thickness 5 ft. : this fills the fissures of the marlstone, forming "clay joints," doubtless made after upheaval by a sinking-in of the clay ; thus the surface of the clay is itself rendered uneven. The clay is capped by a rubbly limestone (β), the zone of *Clypeus Plotii*, Inferior Oolite, here worn

down by recent denudation to a thickness of 6 ft. The whole is overlain by trail formed during the erosion of the coombe, 3 ft. thick at the east end.

Section C, running parallel with the river, and beginning about 100 yards north of the brick-pit. The strata dip N.N.W. along the line of section. The marlstone rock-bed (δ) is at the base. The clay (γ), which overlies it, increases in thickness towards N.N.W., and where measured showed 11 ft. The rubbly bed (β) is here 17 ft. 8 in.; as it dips it is covered by a bed of more homogeneous limestone (α), which, where the section ends, measures 15 ft. This is of finer texture and burns into a very pure lime; it weathers into a white powder and is easily distinguishable from the dirty yellow of the *Clupeus*-grit.

The sections above described may be compared with that given by Hull (*op. cit.*) as occurring in the lane from Fawler to Tapples Wood, on the west side of the valley; the beds here are 14 ft. below the level of those on the east side.

Generalized section of the strata at Fawler:—

	ft.	in.
α . Pure limestone, weathering white	15	0
β . Rubbly yellow limestone, with <i>C. Plotii</i>	17	8
γ . Blue clay, with Upper-Lias fossils	11 ft. to	5 0
δ . Marlstone rock-bed, with Iron-ore	9	0
ϵ . Marlstone sands	11	0
ζ . Blue clay, known by boring for	120	0+

The beds β , γ , δ , and ϵ have been described by previous writers: β is the uppermost bed of the Inferior Oolite series; α should, I believe, be classed with Great Oolite, though it is perhaps below the Stonesfield Slate; in the absence of fossils its exact horizon cannot be determined.

The bed ζ contains, among other fossils, in its upper part *Ammonites margaritatus* and, slightly below, *A. capricornus*; on this evidence it would be referred to Middle Lias; at the same time it is undoubtedly homologous with beds at no great distance classed as Lower Lias by previous workers. See two papers by Mr. T. Beesley, (1) "The Lias of Fenny Compton," reprinted from 'Banbury Guardian,' 1877; (2) "Geology of East portion of Banbury and Cheltenham Railway," Proc. Geol. Assoc. vol. v. no. 4. The life-zones there described seem to agree with those at Fawler, but the character of the rocks is most variable. The Fawler series closely resembles that found in Dorsetshire, where clays beneath the marlstone sands, containing *A. margaritatus*, are called Middle Lias*. If, as I hope, the workings at Fawler are continued, we may expect to find the *palæontological* line between Middle and Lower Lias within another 20 ft.

In order to determine the relations of the bed ζ , the banks of the Evenlode were examined for several miles up stream. The Survey map brings "Lower Lias" down the valley to within $\frac{1}{2}$ mile of

* E. C. Day, "Middle and Upper Lias of the Dorsetshire Coast," Quart. Journ. Geol. Soc. xxx. p. 278, 1863.

Charlbury Railway Station. The only evidence found was at Calsham Bridge. On the right bank of the river, 40 yards below the bridge, there crops out just above water-level a hard rock clearly proved by mineral character and included fossils to be the marlstone rock-bed; above it lies *in situ* a blue clay with Upper Lias fossils, here 40 ft. thick and overlain by Inferior Oolite. This clay can be traced down the valley to within $\frac{1}{2}$ mile of Charlbury.

From Calsham Bridge, where Upper Lias is at the surface, the strata dip gently to the S.E.; a fault N.W. of Charlbury brings up the Marlstone, but does not interrupt the prevailing dip, which continues to a mile S.E. of Charlbury; the rocks then rise again gently till Fawler is reached; here a sharp anticlinal has brought up the lower clays ζ , and broken the beds across, assisting the formation of the coombe: $\frac{3}{4}$ mile S.E. of this anticlinal is a fault, where the Liassic rocks disappear under the Oolites, and the main S.E. dip continues in the direction of Oxford.

APPENDIX (January 1886).—Since this paper was written, in August 1885, little has been done at Fawler to elucidate the relations of the bed ζ , while the weather has rendered field-work very difficult. I have, however, traversed the district between Chadlington and Charlbury, seeking for evidence of the *infra*-marlstone position of the clays there marked on the map as “ g^1 ,” to this end I have examined every ditch and stream. The rocks between the lower clays and the Inferior Oolite would be at least 30 ft. thick here, probably 50 ft., and of these the Marlstone is very characteristic and easily discerned. But clay has been traced from below Inferior Oolite, right down to the river, without a fragment of Marlstone appearing. The only Marlstone seen above Charlbury has been at river-level, and the Lias clay was over it.

DISCUSSION.

Prof. PRESTWICH remarked that the section described was an interesting one. Its working had been abandoned for some years, but it had been recently resumed, and extended considerably to the north. It was within a mile or two of Stonesfield. An interesting point was the thinning-out of the Upper Lias and Oolites, pointed out by Prof. Hull; but this new section showed that the Lower Lias does not share in the thinning. Some fossils from the upper sandy beds of the Lower-Lias clays would seem rather to show that they belonged to the Marlstone.

Mr. TOPLEY drew a sketch of the succession of the beds in the neighbourhood, showing that 50 feet represent all the Cotteswold escarpment, and this thinning accounts for the greater part of the dip of the Inferior Oolite.

Mr. WALFORD said that at Fawler the passage was gradual from the Marlstone to the thin representative of the Cephalopoda-bed at the base of the Upper Lias. Perhaps part of the Upper Lias was removed by denudation before the Inferior Oolite was deposited. At

Charlbury the Inferior Oolite passed without break into the limestones, which the author had called Great Oolite.

Mr. ETHERIDGE said that the paper was confined to the Evenlode valley and was not extended to the country around. *Ammonites margaritatus* was said by the author to be found in the Lower Lias; but it never occurs in that bed, being characteristic of the Middle Lias.

The AUTHOR, in reply, said that *A. margaritatus* occurred within three feet of beds containing *A. varicostatus* (?).

11. *On a recent SECTION through WALTON COMMON exposing the LONDON CLAY, BAGSHOT BEDS, and PLATEAU-GRAVEL.* By W. H. HUDLESTON, Esq., M.A., F.R.S., Sec. G.S. (Read January 13, 1886.)

INTRODUCTION.

DURING the past autumn the London and South-Western Railway Company has been engaged in widening the line between Walton and Weybridge stations, and consequently there has been an excellent exposure of the beds composing the Walton-Oatlands plateau. The communication now made to the Society relates only to such portion of the railway-cutting as extends from Walton station in a west-south-west direction to the boundary of Oatlands Park, and more particularly to that portion of it known as "America." The total length, as measured on the 6-in. Ordnance map, is 1070 yards. This distance is divided unequally by the railway bridge on Walton Common known as "Sir Richard's." The distance between Walton station and the centre of this bridge is 710 yards, whilst the distance from this point to the boundary of Oatlands Park is 360 yards, or thereabouts.

For the purposes of description and convenience of reference, the entire section may be divided into *four* blocks.

Block A extends from Walton station to where the unaltered London Clay in seen to occur *in situ*—a distance of 313 yards.

Block B extends from this to the point where the Bagshot Beds are first seen *in situ*—a distance of 345 yards.

Block C extends from the above to the point where the Bagshots are first cut through to the level of the line, and the hollow filled up with Plateau-gravel—a distance of 165 yards.

Block D exhibits the relations of the Bagshots to the Plateau-gravel, where the latter is most fully developed—a distance of 247 yards.

The above divisions are shown on the generalized section (fig. 1), which may be regarded as a summary, on a small scale, of the sections presently to be detailed. It must be borne in mind that, owing to the exaggeration of the vertical scale, a certain amount of distortion is inevitable.

A few remarks on the topography of the district, and on the formations composing it, together with a brief notice of the literature, may be of use in the first instance.

Walton station is 17 miles from Waterloo; it is situated about midway between the 50-feet and the 100-feet contours (see fig. 2), and lies within the drainage of the river Mole. The line is 68 feet above O. D. at this point. The 100 feet contour is reached at the bridge, where the cutting is estimated to have a depth of 24 feet. At Weybridge station the surface of the ground is marked as 120 feet above O. D. Hence the plateau traversed by the railway, which we may call the Walton-Oatlands plateau, ranges from a little under to a little over the 100-feet line, forming a low *massif* or

Fig. 1.—Generalized Section of the Cutting through Walton Common, September to December 1885. Total length 1070 yards: maximum depth about 27 feet. Depth at the bridge 24 feet†.

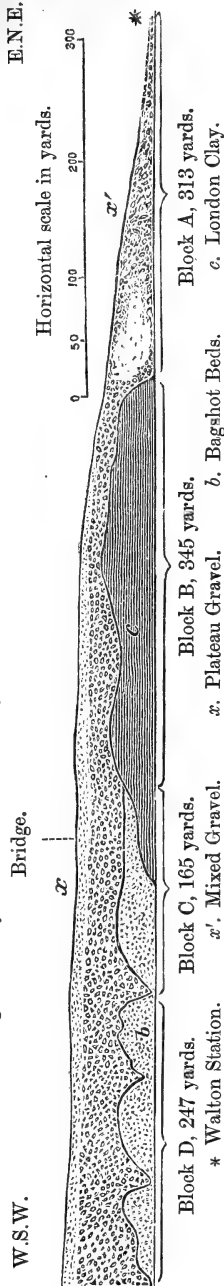
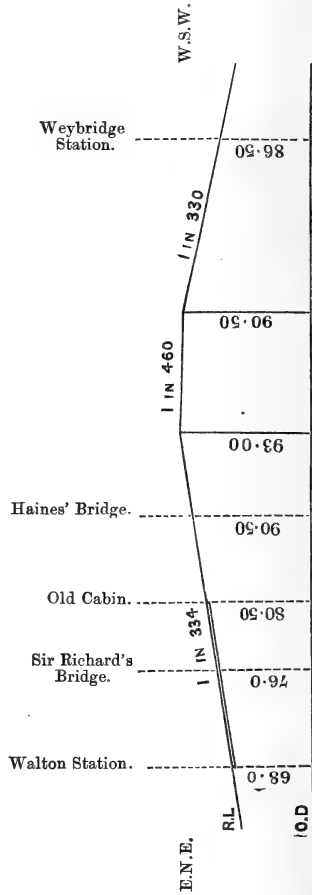


Fig. 1'.—Profile of Railway line between Walton and Weybridge Stations.

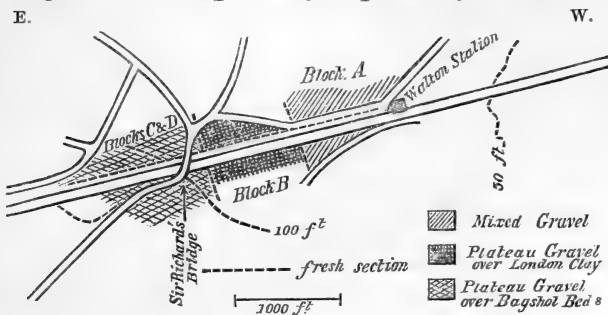


The portion of the line doubled == represents the part shown in fig. 1.

† The official measurements are 2 feet higher in each case; but these comprehend material which probably could not fairly be included in a geological section. The annexed figure (fig. 1'), supplied by the engineer's department, through the courtesy of Mr. J. W. Jacomb Hood, shows the gradients between Walton and Weybridge stations.

promontory, which separates the valley of the Mole from the valley of the Wey. Towards the former the slope is gradual, towards the latter somewhat abrupt. It should also be borne in mind that towards the south-west this plateau reaches the northern slope of St. George's Hill, whose northern brow attains a height of 245 feet, where another and much narrower area is continued towards the south for about

Fig. 2.—Sketch-map showing the position of the section.



one mile. Hence there are two principal plateaux in this district, of which one is about 140 feet higher than the other. It is on these flats, and not by any means on the slopes, that the Plateau-gravel is found*.

The following may be regarded as the principal formations or subformations of the district which we shall have to consider. (See fig. 1.)

- a. Superficial $\left\{ \begin{array}{l} y. \text{ Top sand.} \\ x'. \text{ Mixed gravel.} \\ x. \text{ Plateau-gravel.} \end{array} \right.$
- b. Lower Bagshot Beds.
- c. London Clay.

Of these the "top sand" (y) and the "mixed gravel" (x') are more or less local deposits, not to be found perhaps under precisely similar conditions elsewhere. The Plateau-gravel, also described as "hill-gravel of doubtful age," is well known to dwellers in the Bagshot districts, though it generally occupies higher ground. In fact the Walton-Oatlands plateau is perhaps the lowest elevation where this particular kind of gravel is known to occur. It is briefly described by Mr. Whitaker†, who says, "It is not unlike much of our later

* The following distances of certain points from Sir Richard's Bridge, taking this as a convenient centre, are given :—

Nearest point of River Mole, E. by S.	1 m.	735 yds.
Nearest point of River Thames at Walton water-works, N.N.W.	1 m.	
Oatlands-Park hotel, W.N.W.		1465 yds.
Weybridge station, W.S.W.	1 m.	930 yds.
St. George's Hill, north end of plateau, S.W. ...	1 m.	840 yds.

† 'Guide to the Geology of London,' p. 63.

gravel, which is connected, more or less, with the present valley system, and it is, indeed, sometimes hard to distinguish the two." Prof. Rupert Jones*, referring more especially to the neighbourhood of Camberley, estimates the depth of the Plateau-gravel with loam at 12 feet (p. 433), and he also remarks (p. 438) that "it is not the Tertiary sands that form the actual surface of the Bagshot district, but certain gravels which have been referred to as coating the plateau and hill-tops. The gravel consists chiefly of sub-angular flints from the Chalk with Tertiary pebbles (usually dark in colour); there is also a large percentage of chert from the Neocomian sands of South Surrey, a free sprinkling of quartz in small pebbles (rarely so large as a thrush's egg), and occasional large blocks of concretionary sandstone from the Bagshot Sand." Further on, the same author describes the character, and discusses the origin of the Plateau-gravel, alluding especially to the formation of "iron-pans" therein at various levels, but more especially at the bottom, and shows how such pans have acted in the preservation of the underlying sands.

The Bagshot Beds of the Weybridge district were noticed in Prof. Prestwich's classical paper written in 1847 †. The author observes (p. 381) that "at St. George's Hill near Weybridge the [Lower Bagshot] sands may be traced from the London Clay at the base of the hill to the outcrop of the green sands [Middle Bagshots] about halfway up it, a thickness of about 130 feet." He also says, "This division [viz. the *Lower Bagshot Sands*] reposes conformably on the *London Clay*," adding in a note, "This was well exhibited in the railway-cutting through St. George's Hill. At the end, near the Walton station, I traced the *London Clay* for a distance of several hundred feet passing conformably below the *Lower Bagshot Sands*." This is quoted by Mr. Whitaker ‡ in 1872 in describing the main tract of the Lower Bagshot Beds. Very interesting lithological details of these beds are given by Prof. Prestwich, who, amongst other things, has noted an instance § in Goldsworthy Hill of the lateral passage of these light-coloured siliceous sands into a dark-grey laminated clay. This occurs at the top of the series and immediately below the Middle Bagshots.

DETAILS OF THE SECTION. BLOCK A. (See fig. 3.)

The line at Walton station is on the level of the country, and as we proceed westward the rise for the first 60 yards is so slight that no certain exposure is yielded; such indications as exist are of a sandy character. The first bed which becomes distinct is the "Top Sand," here about 2 feet thick. At the point marked *m* (fig. 3) we find indications of the "Mixed Gravel" series (*x'* of the general section), and water is noted in the gutter for the first time. The

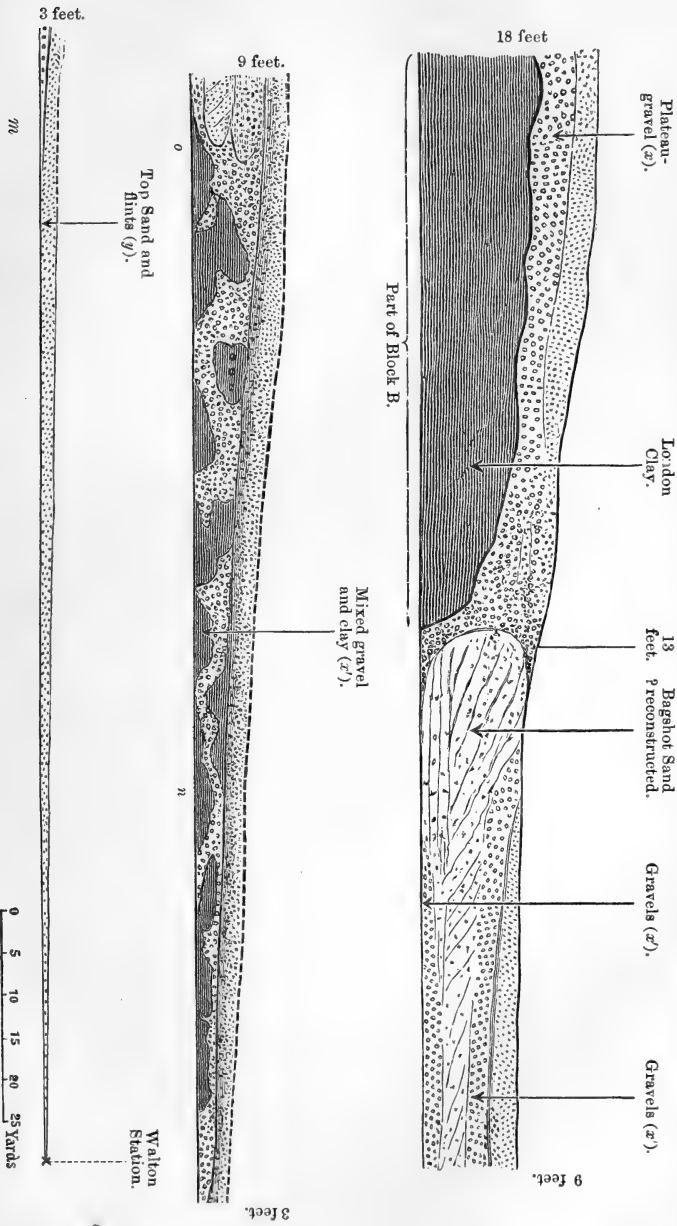
* "Excursion to Camberley," Proc. Geol. Soc. vol. vi. p. 329, and "Geology and Physical Features of the Bagshot District," *ib.* p. 429.

† Quart. Journ. Geol. Soc. vol. iii. p. 387 *et seq.*

‡ 'Geology of the London Basin,' p. 315.

§ *Loc. cit.* p. 382.

Fig. 3.—*Enlarged Section of Block A and part of Block B. General direction from W. to E.*



remainder of block A, with the exception hereinafter to be mentioned, is made up of this series overlain by 2 or 3 feet of a "Top Sand," rather flinty in its lower parts. This mixed gravel and clay makes a very wet line hereabouts. At the point *n* (192 yards from the station) the following section was disclosed:—

	ft. in.
Made surface of old path	0 4
(<i>y</i>) Top Sand, sometimes with bleached flints towards the base	3 0
(<i>x'</i>) Clay, sand, and pebbles with bleached flints	2 10
Total.....	6 2

The succeeding 50 yards discloses still more of this curious mixture. As a whole, its character is strongly argillaceous, but neither on the line nor in the section can a blue clay be discovered. Lumps of brownish clay with pebbles occur in the midst of the sands. Some of these lumps may be in continuity with the London Clay beneath; but, so far as we can judge from this section, the whole must be regarded as a disturbed series, and classed with the superficial deposits.

At the point marked *o* (about 240 yards from the station) the clay and sand with pebbles or "mixed series" is jammed against the end of an included mass of what appears at first sight to be yellow Bagshot Sand. The true nature of this mass of sand, 70 yards in length, fully 12 feet thick at the west end or "corner," and tapering to about 2 feet at the east end, is by no means clear. If we examine it where narrowest, it can be regarded as nothing more than a tongue of sand in the "mixed series," since the gravel underlies it as well as overlies it; but further up, where it gets thicker, nothing can be seen to underlie the mass, of which the lowest visible bed is a wet sandy loam. Where thickest, the yellow sand is much current-bedded with inclination towards the east, but chiefly in the middle and upper portions. The sand of these false-bedded portions is in no respects like the sand of the main mass of the Lower Bagshots, being entirely devoid of the laminated character, and also having the grains larger and more unequal. It has more resemblance to the lowest bed of the Lower Bagshots (No. 1) presently to be described, but is coarser and more unequal in the grain. Both, however, are sharp, clean sands, in comparison with the "soft sand" of the main mass of the Lower Bagshots hereabouts. It is a singular accident that the almost ubiquitous "Top Sand" is absent where this mass comes to the surface. The whole terminates in a most remarkable and sudden manner (see fig. 3, junction of blocks A & B, 313 yards from the station) against an equally sharp and sudden rise of London Clay covered by Plateau-gravel. The space between the clay and sand is filled with a mixture of gravel and loose yellow sand, and this gravel passes for some distance underneath the solid mass of yellow sand itself.

The above remarks are strictly descriptive, but the "mixed series" and the sudden termination of the yellow sand cannot fail to provoke

a certain amount of speculation. In the Survey map, which gives the superficial geology of London and its environs, Lower Bagshot Sand *in situ* is represented here; and a fringe of Lower Bagshots is shown all along the eastern margin of the great mass of Plateau-gravel to which allusion has been previously made. When first I saw this place it occurred to me for a moment that there might be a fault here which had let down the Bagshots, so as to preserve them from destruction, and also accounting for the singular position in which the yellow sand is found in reference to the London Clay. Something of this kind there may be, yet it could hardly account for everything on the supposition that the yellow sand is nothing more than a mass of Lower Bagshot *in situ*. Besides, the lithology is against this supposition. On the whole I am rather inclined to believe that the upper and more false-bedded portions of the yellow sand have been reconstructed with a slight intermixture of foreign material. The only portion, then, really *in situ*, on this supposition, is the lowest part of the mass, beneath which no gravel can be detected. It is perfectly obvious that the eastern end belongs to the "mixed series;" and perhaps the whole of the "yellow sand," with the exception of the horizontally bedded sands at the base, should be classed with the "mixed series" (*x'*).

This latter may be regarded as constituting a sort of passage between the Plateau-gravel and the Thames-valley gravel—a view which accords well with its position on the slope. If this be correct, it is just possible that the old margin of the Mole-valley inlet may at one time have been at the spot where this reconstructed Bagshot Sand now abuts against the steep surface of London Clay covered by Plateau-gravel. The action of coast-ice, too, may have had something to do with the peculiarities to be noted hereabouts, and some of the sand lumps in these gravels may have been frozen, and so kept together; but I am inclined to think that reconstruction by water will account for most of what we see as regards the yellow sand.

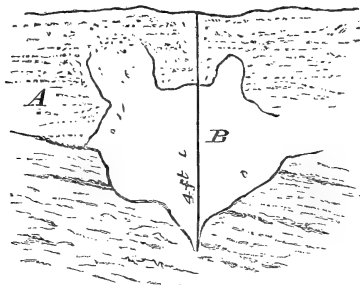
On reexamining this section in the early part of January 1886, the improbability of this yellow false-bedded sand at the "corner," representing Bagshots *in situ*, as indicated in the Survey map, was still more strongly impressed upon me, since the general structure of the sand and the entire absence of the thin argillaceous layers is so different from what obtains even in the basement-bed of the Lower Bagshots. These remarks apply more especially to the upper part of the deposit, where a singular appearance was noted towards the surface, which I have endeavoured to represent in fig. 4.

The following notes as to the character of the two varieties of sand are appended:—

A. The main mass or false-bedded series. The quartz grains are irregular, and are often pebbles reaching a diameter of 3 millim. Bleached flint chips 5 or 6 millim. in diameter are not uncommon. It contains the elements of the basal sands of the Lower Bagshots, together with rounded grains of dull quartz of the size before mentioned. Resembles in many respects the sands of the Plateau-gravel, but cleaner.

B. Contains pebbles. One of iron-sandstone between 50 and 60 millimetres in longer diameter, also a bleached angular flint of about the same size. The quartz grains are more rounded, duller, and more unequal than in A.

Fig. 4.—*Singular Appearance in the false-bedded Sands at the "Corner."*



B represents a mass of sand irregular in shape and devoid of bedding, enclosed in the false-bedded series (A). Its outline is ill-defined, much more so than in the figure, and but for the complete absence of bedding one would hardly notice it. The current-bedding of A, which inclines to the eastward, appears to suffer no interruption.

Block B. (Fig. 1 and part of fig. 3.)

Commencing with the sudden appearance of the London Clay *in situ*, the second block comprises that portion of the cutting where the London Clay forms the sides, and is directly overlain by the Plateau-gravel. This is the longest block of the four, and perhaps, on the whole, the most monotonous. Within this space the portion of the London Clay exposed above the permanent way, after rising pretty sharply at the "corner," constitutes a sort of plateau of denudation, ranging from 10 to 15 feet above the line. The surface is undulating within these limits, more especially towards the western extremity of the block, where a shallow valley may be noted. Beyond this the curve of the London-Clay surface rises to 13 feet, just before commencing that well-developed drop which brings in the bottom beds of the Lower Bagshots on the west. No fossils or *Septaria* were observed by me. The clay, when wet, is bluish and tenacious; when dried it is seen to be moderately sandy, and of a darkish grey. The discoloured layer at the top is mostly of a dull red, but varies to brown and yellow. It is usually less than a foot thick beneath the gravel, except where there has been a slight rupture of the surface, in which case the zone of discoloration is wider. These phenomena are very similar to what was observed in the "red loam" or "wet clay" of the New-Law-Courts site*.

* See paper by Hudleston and Price, Proc. Geol. Assoc. vol. iii. p. 44 (1872).

The following note is given as to the character of the dried clay. The London Clay of the Walton cutting breaks into greyish lumps made up of finely granular matter with sparkling points. These are mostly clean quartz, with perhaps a speck here and there of white mica. These lumps crush into a fine grey and subangular powder. There is considerable equality amongst the constituent granules, which have an average diameter of .08 millim. The granules are mainly quartz, but nearly always invested with a greyish white kaolin-like substance, which breaks off in very thin flakes; it is by means of this substance that the aggregation of the quartz granules is effected. As in the Lower Bagshots there is a moderate quantity of green grains, both pale and dull green, always very small. Pieces of an iridescent mineral, probably sulphide of iron undergoing oxidation, may also be noted.

One of the slides exhibited represents the very coarsest particles after washing, and here a certain number of larger quartz grains may be noted; these are mostly rather rounded at the edges, and present an exceptional feature as regards size. Amongst the thin flakes of the kaolin-like substance are numerous specks of quartz (much smaller than the grains), but notwithstanding their extreme smallness in very good optical condition. This is shown in another slide.

When the section was very fresh the bedding of the London Clay was almost invisible, and the clay looked like a mass entirely homogeneous. Weathering has subsequently developed the bedding, especially of the upper layers, which, on the whole, are more sandy than those of the base of the cutting. It is only in a few places that the bedding is visible. For instance, wherever the sides of the cutting have been sloped, the sliding forward of the superincumbent gravel has effaced every feature; but there are some portions towards the centre of block B where the bedding is very well seen. The occurrence of ribands of light-grey sand, near 2 inches in thickness, helps to bring it out more distinctly. Where visible there is a dip of about 1° , or rather less, down the line, *i. e.* towards the west. If this is continued the beds at the junction with the Bagshots must be higher in the series than those in the middle of block B. Besides the ribands of sand already mentioned, lenticular patches of small extent may be noted. The deficiency of calcareous matter is probably the cause of the absence of *Septaria* throughout the London Clay of this cutting.

A further microscopic examination of the sand-grains in the London Clay shows that angular quartz, mostly of a highly vitreous kind, immensely preponderates over all other constituents, which latter may be regarded more or less as mere accessories. In the clayey or unctuous varieties these grains are often more like quartz chips or splinters, and range from $\frac{1}{30}$ to $\frac{1}{40}$ millim. in diameter, but with an admixture of a larger size, from $\frac{1}{8}$ to $\frac{1}{10}$ millim., which were originally more cubical in shape, and are sometimes a little rounded. This seems to point to two independent sources for the material of the deposit. In this variety the black specks are mostly

due to iron mineral. Glauconite granules were not observed; but there are a few angular fragments of a clear green mineral substance.

In the more sandy beds there is not quite such an immense preponderance of quartz, since we find more "glauconite," of a pale greenish grey, and in some cases of a marked green colour. The quartz is more frequently cubical in form, but rarely rounded; vitreous varieties predominate. The size of the granules is perhaps from $\frac{1}{10}$ to $\frac{1}{12}$ millim. but with stray pellets up to $\frac{1}{8}$ millim. Within the above limit, there is considerable variety in the different beds, more especially as regards the amount of "glauconite." In the ribands of sand before mentioned the grains are quite clean, and may be examined without washing. The sample is very similar to the washings obtained from the sandy clays, but the general colour of the mass is rather paler.

The Plateau-gravel over the London Clay.—At the "corner," where everything is muddled up, pieces of discoloured sand may be noted in the Plateau-gravel. As a rule, throughout the eastern portion of the block, even including the "Top Sand," here very thin, it does not exceed 6 feet in thickness, but further westwards is seen to increase. The undulations in the London-Clay surface are compensated by the irregular depth of the Plateau-gravel. Over the clay area the proportion of sand is less. Pebbles and regular bedding predominate in the lower portions; the upper part of the gravel is more messed, contains more angular flints, and is, on the whole, more sandy. The downward action of solvents has caused the lower pebbles to possess the strongest coating of iron oxide. In some places there is a thin ferruginous pan at the junction with the London Clay; and in one place this has assumed rather considerable proportions. The higher pebbles and subangular flints are more or less bleached.

The preceding considerations lead us to conclude that the line of London Clay on Walton Common, in maps showing the solid geology, should be advanced westwards till within 30 yards east of the centre of Sir Richard's Bridge: whilst, if shown on the permanent way, the boundary-line must be advanced considerably beyond that bridge.

BLOCK C. (Fig. 5.)

Though the shortest of the blocks, perhaps this is the most interesting, since we here obtain evidence of the relations of the basal beds of the Lower Bagshots to the London Clay. Fig. 5 is an enlargement of that portion of block C which lies west of the centre of the bridge.

As the curve of the London-Clay surface sinks in a series of minor undulations towards the west, traces of the lowest bed (No. 1) of the Lower Bagshots may be noted about 30 yards east of the centre of the bridge. It is a yellow sand, nearly 2 feet thick here, and terminates with a very blunt point against the London Clay. At the centre of the bridge the following section was observed:—

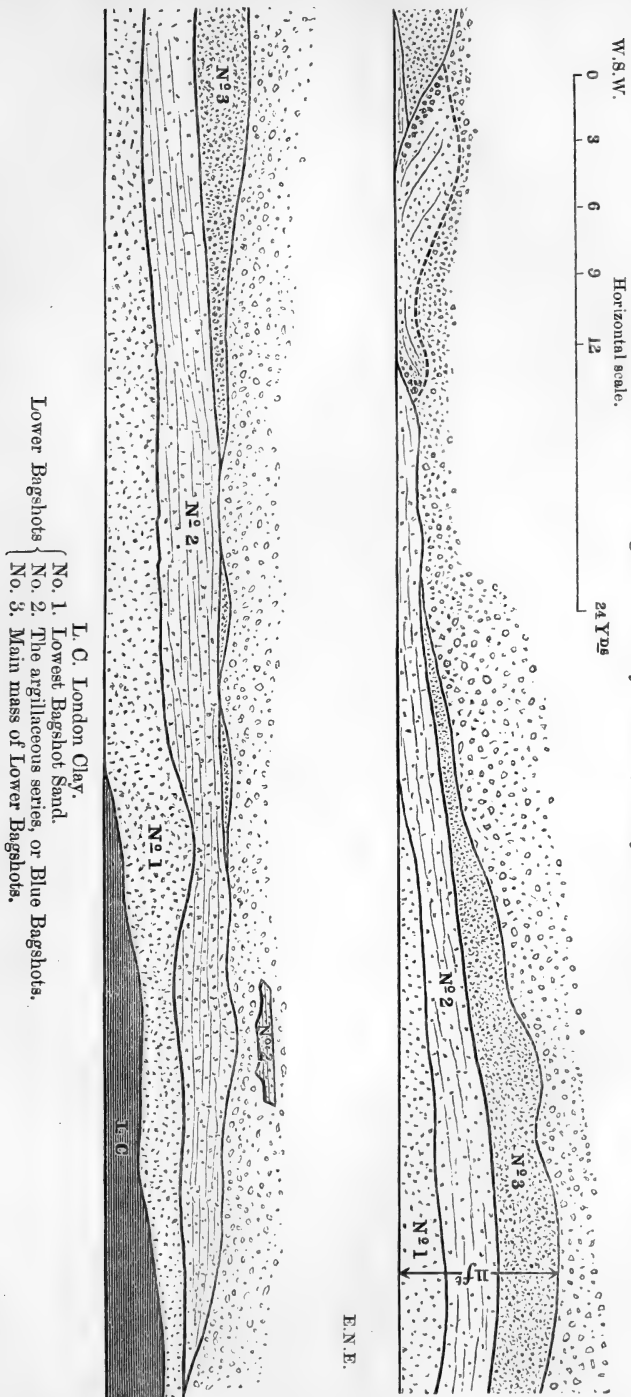


Fig. 5.—Part of Block C, enlarged.

Section at Sir Richard's Bridge.

		ft. in.
The superficial beds (estimated)		17 0
	ft. in.	
No. 1. Lower Bagshots... {	Yellow sand.....	0 5
	Buff sticky clay	0 8
	Sharp yellow sand with ochrey layers	0 11
	Discoloured clay	0 6
London Clay	Blue Clay.....	4 6
		<hr/>
	Total	24 0

No. 1 is rather nipped here by the superficial beds*, but presently acquires considerable thickness; at the west end of the bridge it is seen to be covered by No. 2, as shown in the figure. Originally this bed may have overlapped No. 1, but there is now no trace of it east of the bridge. One might as well try to diagnose the colour of a chameleon as to describe No. 2 with any pretensions to absolute accuracy. Speaking generally, it is a very dark sticky clay in thin laminae: but it is so much permeated by sands of all colours, and changes, within such short distances, to brown and red clays, with thin pans of iron-rust, that no single description will suffice. The general effect produced in section, by contrast with the sands above and below, is a dark blue; hence I call this bed, or series of beds, the "Blue Bagshots." The average thickness is about 4 feet.

Already, at the point where the London Clay falls below the level of the permanent way, the Bagshots have attained a thickness of 10 feet, partly made up of No. 2, but principally owing to the great expansion of No. 1, which is very irregular and false-bedded, sometimes pinched by No. 2, and sometimes expanding suddenly. This false-bedding frequently changes in direction, and especially on either side of a thin seam of brown clay, as may be noticed in the annexed sketch by Mr. Foord (fig. 6). A very few inches of No. 3, which represents the main body of the Lower Bagshots hereabouts, contributes to the total of 10 feet at this point.

About 80 yards west of the centre of the bridge the Bagshots attain their maximum thickness in block C. This is made up as follows:—

No. 3. Buff sands, partially laminated.....		ft. in.
		4 2
No. 2. Upper clay	ft. in.	
Red sands	0 10	
Lower Blue Clay.....	1 10	
No. 1. (Base not seen)	1 2	3 10
		<hr/>
Total		3 0
		<hr/>
	Total	11 0

West of this, No. 1 is lost on the dip, whilst No. 2 is cut out as shown in fig. 5, together with the overlying bed. The consideration of this feature belongs more properly to the fourth block (D).

* Perhaps the construction of the new arch may have helped this.

Fig. 6.—*Part of Block C. The Basement-beds of the Lower Bagshots, west of Sir Richard's Bridge, Walton Common.*
W.S.W. E.N.E.



In block C the contrast of colouring is very effective. The dark blues of the moist clays, and the reds, chocolates, yellows, and whites of the sands produce a pleasing and striking effect, which prolonged exposure to the atmosphere will doubtless tone down. At first sight there is a superficial resemblance between the London Clay of the section and No. 2 of the Bagshots, but the former is more homogeneous, and not laminated, and the thin ribands of intercalated sand, which it contains at rare intervals, are regular in their occurrence and deposition.

The entire section is strongly suggestive of unconformity between the London Clay and the Lower Bagshots at this point. It would be impossible to find a sharper lithological contrast than is presented by the London Clay and the yellow sands of No. 1, the lowest Bagshot bed. At the same time the stratigraphical evidence seems also to point in the same direction. There is no conformability between the London-Clay surface and the undulations of No. 1. On the contrary, where the surface of the London Clay presents a slight depression this bed not seldom shows a protuberance. To me it seems probable that these loosely aggregated and current-bedded sands were deposited against the eroded slope of the London Clay, just as we now see them. An important feature in the case is that the London-Clay surface rises at least 4 feet higher on the east than any part of the lowest sand-series (see fig. 1). Doubtless both the blue beds (No. 2) and the buff laminated sands (No. 3) overlapped, and have been removed by denudation; but this does not alter the fact that the lowest bed of the Bagshots is seen to abut against a surface of London Clay, and not to conform to it. Moreover, the westward slope of the London Clay visible in section, which falls from 13 feet to zero in about 100 yards, has not by any means the appearance of a true dip-slope. On the contrary, the undulations of its surface seemingly point to erosion previous to the deposition of any of the Bagshot beds*.

As before observed, the very marked change in the lithology also points in the same direction. There are, of course, numerous instances where a clay series *gradually* becomes a sandy series, and yet where the change of colour is often rather sharp, although the lithological differences at the point of contact of the two colours may not be very strong. But in this case the contrast between the grey London Clay, sticky and dark coloured, and the bright-yellow sand of No. 1, incoherent and full of false-bedding, is fairly borne out by an examination of their intimate composition. A brief notice of the lithology of the London Clay at this place has already been given,

* It is much to be regretted that the works of the bridge prevent a thorough understanding of this, the most critical part of the whole section. The mean slope of the London-Clay surface at this place may be taken at 1 in 23, which gives an angle of about $2\frac{1}{2}^\circ$ to the westward, or not very much in excess of the observed dip of the London Clay of the central portions of block B. Unfortunately that portion of the London Clay which underlies the Bagshots is too much "muddled" for the bedding to be made out. If we could prove with certainty that the ends of the beds were truncated by the slope, the evidence of unconformity would be complete.

and I will now proceed to make a few observations on the Bagshot Sands of this place, selecting No. 1 as the type, because the constituent grains are comparatively large, and because, where it is thick and current-bedded, the grains are remarkably free from ochreous or other investment.

The sample now under description was taken from the very thickest part of the bed and towards the middle of it: it is a light-grey sand with black specks, passing laterally into bright-yellow sand. The following are the chief constituents in order of abundance:—

(1) Vitreous quartz, mostly angular: size of grains ranging from about 0.9–0.27 millim., average perhaps 0.4 millim. This forms the bulk of the sand.

(2) Opaque and coloured quartz, partly, perhaps, chalcedonic: grains often rounder and slightly larger than in the other variety.

(3) Angular, subtranslucent fragments, black in reflected light, believed to be chips of flint or chert. Also angular fragments of a dull black mineral, probably the "lydite" of authors.

(4) Green renuline granules, some of which must evidently have been casts of organisms, probably Foraminifera. These granules are smaller, on an average, than the quartz grains, and are frequently fractured, appearing as fragments. They are not sufficiently numerous to materially affect the colour of the sand. Doubtless this is the so-called "glauconite," which, in the present case, I take to be mainly a hydrous ferric silicate, with variable proportions of alumina and small quantities of protoxide bases.

(5) Granules of iron-oxide here and there; magnetite extremely scarce.

Supplementary Note as to Nos. 1 and 2 Bagshots.

No. 1. A fresh sample of this clean bright sand confirmed the features already indicated. Many fine examples of glauconite in renuline granules, some after *Globigerina*. The average size of the granule in this sample was estimated at $\frac{1}{2}$ millim.

Noted an oval grain of quartz, $2\frac{1}{2}$ millim. in length. The dark flakes are evidently some chalcedonic form of silica; but how is it that they are not bleached like the flint chips in the sands of the gravels? A single small fragment may be a bleached flint chip.

No. 2. The sandy beds of No. 2 contain a considerable amount of iron mineral. The red sands of this series and associated clays contain quartz pebbles up to 4 and 5 millim. in diameter.

About the junction of Nos. 1 and 2 are numerous woody fragments bored by *Teredo*, and afterwards partly pyritized. Very often hardly anything is seen but the form of the tube associated with brown oxide of iron.

The next bed which has to be considered is No. 2, or the Blue Bagshots: this is mainly argillaceous, but with seams of sand included, which are often rather coarse and very ferruginous. As before remarked, the lithology of this bed varies so much within short distances that a detailed description would be interminable.

Some of the clay is intensely greasy. There is one phase which occurs so frequently that it may be deemed characteristic. It is where the dark unctuous clay is pervaded in a very singular manner by very fine grey sand, which can neither be said to occur in seams nor in layers. This peculiarity is recognized by well-sinkers, and serves to distinguish it from the London Clay. Towards the south-east of St. George's Hill, about a couple of miles from our section, there is a well which is said to go through a great many feet of "blue sandy stuff," which is not London Clay. Part, at least, of such a well-section may be in the "Blue Bagshots;" but if so, they must have thickened enormously. To a certain extent one is prepared for this thickening by an inspection of the vertical section of the Bagshot strata disclosed in the trial-boring for the deep well at Wellington College supplied by Mr. Irving*, who gives no less than 35 feet of "blackened marl and clay, laminated in its upper portion." That author remarks, with reference to the Wellington-College bore-hole, that the uppermost 25 feet of the bed referred to are strongly laminated; the remaining 10 feet pierced have more the character of London Clay than anything else. "Here then," he says, "we seem to find a *passage of the London Clay into the Bagshot Sands.*" I would only remark that nothing whatever of the nature of marl has occurred to me in connexion with any of the Bagshot beds of our district; indeed the amount of calcareous matter in all the beds is exceedingly small.

On the whole, No. 2 of the Walton-Common section is tolerably impervious; and, whether it is in contact with the Plateau-gravel, or with higher beds of the Bagshot series, there is generally a strong ferruginous pan at the top of it. Undoubtedly this is the bed which has to answer for some of the peculiar water which the Lower Bagshots are known to afford. The well-sinkers say that "people don't like 'blue-clay' water; it has got a skin like grease." This may of course, in some cases, refer to water at the top of the London Clay; but I am inclined to think that in the Oatlands district it mostly refers to the water of the "Blue Bagshots." A well-sinker, of the name of Gray, whom I saw lately, tells me that he sank a well on the slope between Oatlands Park and Lower Weybridge, and that at about 30 feet below the mouth of the well he went through a bed of coal in the "blue stuff." This bed of coal was $1\frac{1}{2}$ inch thick, and burnt readily: he calculates the position of this bed to be about 10 feet below the level of the river Wey. Hence there is a probability of organic contamination in many places where the "blue stuff" is developed.

No. 2 corresponds most probably with the Ramsdell Clay mentioned by Mr. Whitaker †, who observes, "that on a close examination it was also remarked that the Ramsdell Clay bore a kind of resemblance to the pipe-clays of common occurrence in the Bagshot Beds, and for this reason probably it is adapted for making tiles (a purpose for which London Clay is seldom suitable), being an impure

* Proc. Geol. Assoc. vol. viii. p. 144, and Q. J. G. S. vol. xli. p. 494.

† 'Geology of the London Basin,' p. 312.

or imperfect pipe-clay, intermediate in quality between the true Bagshot pipe-clays and the more sandy beds of ordinary London Clay." The same author mentions* that at a place called Hartley Row only one foot of sand intervenes between the Ramsdell Clay of the Lower Bagshots and the blue London Clay. This 1 foot of sand possibly is the attenuated representative of No. 1 of the Walton-Common section. The thickness of the Ramsdell Clay at Hartley Row is stated to be 8 feet, so that the total thickness of the two basal members of the Lower Bagshots is nearly the same at both places, only the distribution is different. When this No. 2 group has been exposed for some time, it is highly probable that browns and buffs will be the prevailing tints.

We next come to the consideration of No. 3, which represents the basal portion of the main mass of the Lower Bagshots as developed in this area. The lowest portions, just over the Blue Bagshots, are generally of a darker buff than those higher up, and, on the whole, rather larger in the grain, though smaller than Bagshots No. 1. Colour, when wet, like common brown sugar, feebly coherent, except where very small ochreous lumps exist. The elements of this sand are mainly those of No. 1 already described. The constituent granules, besides being smaller, are more equal and less clean. They average about 0.16 millim. in diameter. Little flakes of white mica are rather more obvious, and there is more argillaceous matter, generally spread in very thin sheets throughout the bedding. The green grains, both pale and dark, are also fairly abundant.

At the bridge, and for about 25 yards to the westward of it, this division of the Lower Bagshots has been cut out entirely. Presently we perceive little outliers of it cemented to the ferruginous base of the gravels by more or less of an iron-pan (see fig. 5). Traced towards the west, it is found increasing in thickness for a while, until cut out entirely by the first gap which forms the boundary of block C.

Plateau-gravel, &c. in Block C.—The superficial beds of this division are usually from 14 to 15 feet thick, showing a considerable increase over what obtains in the London-Clay area: they are also more sandy. For some part of the distance the Plateau-gravel reposes on the "Blue Bagshots;" and there is an appearance, as indicated in fig. 5, of a portion of this bed having been incorporated. Towards the end of the block, as we approach the first gap, large masses of reconstructed sand, with only a few layers of pebbles, constitute the lower portions of what we must still call the Plateau-gravel. These sands are mainly derived from the Bagshots, such as we see in this district; but they contain other elements in addition. It is not always easy to draw the line between the superficial beds and the unshifted Bagshots.

BLOCK D. (Fig. 1.)

In this block the *Bagshot Beds* are represented by No. 3 alone, with the exception of a faint trace of the "blue beds" just at the

* *Op. cit.* p. 314.

commencement. They have been deeply eroded, and are cut down to the level of the line, and even slightly below it in three places, which may be called respectively No. 1 gap, No. 2 gap, No. 3 gap, going from east to west. The lithology here is of the usual character, a fine and equally grained "soft sand," faint yellow to buff, and even brownish or reddish at top, where much percolated. Slight clay laminations occur throughout, helping to show the bedding, which is pretty regular and current-bedded only for short distances. The colour-banding, as distinct from the bedding, follows the curves of the eroded surface, showing clearly that the reds are due to infiltration from above. This is, perhaps, better seen beneath the shallow basins than in those more deeply excavated. The average thickness of the Bagshots exposed in block D, may be taken at about 7 feet.

The Plateau-gravel of Block D.—Assuming the cutting to be about 26 feet deep here, a thickness of about 19 feet must be assigned as the average of the superficial beds; whilst, as we have seen, in some places they occupy the entire depth of the cutting. No. 1 gap is about 9 yards across. On the east side the "Blue Bagshots" are cut sharply off, and the superficial deposits in the bottom of the cavity conform, more or less, to the sides, which are lined with a layer of mixed flints and pebbles holding up a mass of reconstructed sand about 4 ft. thick, overlain by other masses of reconstructed sand with pebbles, showing a different stratification.

Such masses of sand are often disposed in nearly horizontal layers, between which much current-bedding is exhibited. At first, from their external resemblance to the Bagshot Sands *in situ*, I mistook them for these beds, fancying that tongues of gravel had been thrust between the divisional planes, or even in some instances that masses had been transported bodily. I think it is quite probable that in some cases my former interpretation may be the correct one; but, in a majority of instances, a close examination of the sands in the Plateau-gravel will show that they are coarser, more unequal in grain, and devoid of the clay laminations so characteristic of the beds on which they repose. Although the material is mainly the same, the one has been a turbulent, the other a comparatively quiet deposit. That section of the Plateau-gravel which lies between the first and second gaps consists, especially in the lower, though not quite the lowest parts, of immense masses of this kind of sand, which are often somewhat ferruginous.

Even here the actual base of the Plateau-gravel is for the most part occupied by beds in which the regular Tertiary flint pebble is largely represented. These gravels present a sort of rude stratification, especially conformable to the shallower depressions of the Bagshot surface, which, as a rule, they fill up in a series of concentric layers, sometimes loose, more often cemented by deep brick-red iron-oxide, with here and there a streak of black oxide of manganese above. Under these circumstances there is no difficulty in drawing the line between the Bagshot Sand and the Plateau-gravel: the contrast, in fact, is exceedingly sharp. The hollow about halfway between the first and second gaps is cut down to within three or four feet of the

permanent way. This is filled with bedded masses of flint and flint-pebble gravel, of a rich chocolate colour, which produce quite an imposing effect when contrasted with the fine and pale-coloured sediments of the underlying Bagshots.

It is, however, between the second and third gaps that the contrast of colour is the most marked. Here the hollows are filled with thick courses of brick-red gravels, the stain of which sometimes extends, in varying tints of paler red, through a portion of the underlying beds, until a line is reached where the percolation has been arrested. Beneath such a line the Bagshot Sands look almost white by contrast. When the section was fresh, these colours were really gorgeous, and quite astonished the navvies. The fact is that the vicinity of the third gap, at the western extremity of block D, marks the lowest point of erosion of the Bagshot Beds, which continue to rise beyond these limits. This part of the Plateau-gravel, therefore, must represent a line of underground drainage, a circumstance which helps to account for the accumulation of iron-pans towards the base; since the more soluble matters, chiefly salts of iron in this case, are sure to find their way to the bottom, and when a pan is once formed, the coating of the pebbles above it continues to increase.

The Plateau-gravel may be truly said to attain its maximum development at the third gap, which almost coincides in position with the boundary between Walton Common and Oatlands Park, the latter commencing just where our section terminates. Deducting a yard for "Top Sand," there must be 24 feet of gravel here. As usual, pebbly gravels, more or less conforming to the eroded surface and enclosing a certain proportion of false-bedded sand, fill up the principal hollow. Some of the masses of sand here may be fragments of the original beds, either torn off by currents or floated up by ice; but, if so, the structure has in most cases been considerably modified.

At this point we may roughly divide the Plateau-gravel into three vertical sections. The lower portion is such as I have endeavoured partially to describe. The middle portion is more sandy, having no doubt been largely derived from the Bagshot Beds of the adjacent district, but also containing coarser material. It is often fairly well bedded for short distances. The upper division is the most constant throughout the entire area. It is usually the least bedded of the three, has a greater proportion of large angular flints, cherts, &c. Sand occurs in masses and pockets, and is sometimes rather argillaceous and dirty, but always much coarser than the "soft sand" of the Bagshots. If there is bedding it is often much twisted, so that the apparent lines of stratification lie at all inclinations, and are sometimes curved or contorted. It is not contended that these divisions are by any means constant; but it is evident that the middle division is largely expanded throughout block D; and this circumstance helps to account for the unusual thickness of the Plateau-gravel hereabouts. The Metropolitan Convalescent Asylum (109 feet above O. D.) is 220 yards from the end of the section on the south side of the line; and here a well, said to be 30 feet deep, appears to have been sunk entirely in the superficial beds.

CONCLUDING REMARKS.

Having completed the description of the section through Walton Common, it only remains to say a few words relative to the neighbourhood. As regards the composition of the Plateau-gravel *generally* throughout the district, it would seem to conform in the main to the description already quoted from Prof. Rupert Jones's notice. The coarse brown quartzose sands are sometimes agglutinated and earthy, and bespeak an origin very different from that of the "soft sand" of the Bagshots of this neighbourhood, although much of this fine-grained material may also be noted. What few green grains there are, present a different appearance from those in the underlying Bagshots; cherts, derived mainly from the Lower Greensand, are fairly numerous; but Sarsen stones are decidedly rare, only three or four having come under my notice during the excavations; one of these might have been about 2 ft. 6 in. in length. No quartzites of any size have been noticed, and there is likewise a complete absence of the hard materials of the Northern Drift; everything bespeaks a local and southern origin, as all previous observers have already intimated. I must admit that the numerous brown flints are very apt to be regarded as possibly cherts; some are exhibited, they have in many cases lost all the usual characteristics of ordinary chalk flint, and some specimens are so polished externally as to resemble little Sarsen stones. There is one with a specimen of *Micraster*, which proves the true nature of this brown flint. They must have undergone some peculiar action. Indurated sandstones from the Lower Greensand are more abundant than actual chert; but there is a piece of *Pholas*-bored wood, now in the condition of chert, and some other curious forms.

Whilst on the subject of the contents of the gravel, I would direct attention to a hollow ferruginous box, as a sample of several similar ones, which occur as pseudo-pebbles at the base of the gravel in some places, and especially near the west end of the section. These boxes lie at the junction of the Bagshots with the gravel, and appear to represent clay-galls, torn from the loams of No. 3 (which occur in force further down the line), around which a deposit of brown oxide of iron has formed. The reticulations in one of the specimens exhibited represent, it is believed, casts of shrinkage-cracks. Sandy loams of various colours are found inside.

The Top Sand.—It would scarcely be right not to append a brief description of this all-pervading deposit, which plays such an important part in the economy of the Walton-Oatlands plateau. Supposing any one, desirous of ascertaining the nature of the soil in Oatlands Park, consulted a map of the solid geology, he would of course discover that it was situated on the Lower Bagshots. If the inquirer further wished to ascertain the nature of the *surface*-deposits, he would find them described as "Hill-gravel of doubtful age." But this Hill- or Plateau-gravel only exercises a secondary influence on the soil of Oatlands Park, since every plant desirous of reaching it must needs travel through a yard of most unfruitful

sand. This peculiarity explains why splendid forest trees, oaks, beeches, &c. flourish on a surface which you can scarcely coax into growing a radish. When once such trees get their roots into the slightly clayey gravel of the plateau they are safe; meanwhile innumerable firs with their wide-spreading roots are luxuriating in the Top Sand.

As regards its composition, it is essentially a mixed deposit, containing a few split flints, which become more abundant lower down, also numerous large and often rounded quartz grains, the presence of which serves to distinguish it at once from the "soft sand" of the Bagshots. On examining the finer portions under the microscope, it becomes probable that these latter, directly or indirectly, have contributed largely to its formation; but there is a greater preponderance of quartz together with rather more investment of the individual grain. The "green grains" are very scarce, but there are several granules of iron-oxide, some of which adhere to the magnet. Nearer the surface, where a carbonaceous investment discolours the granules, the sand has a blackened appearance, and this is what passes for soil in Oatlands Park.

By way of comparison with the section through Walton Common, I append a section in the village of Oatlands, close to the 100-feet contour:—

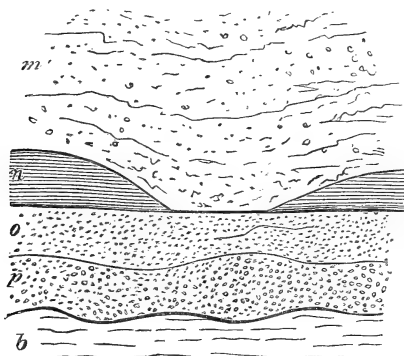
		ft.	in.	
Top Sand, &c.	{	1. Discoloured sand with root fibres, and occasionally large flints	2	0
		2. Band of flints and flint pebbles in the sand.....	0	2
		3. Foxy sands, sharp in the upper part, but rather more earthy towards the base	1	0
		4. Line of flint much bleached: variable in thickness.	0	2
		3	4	
Plateau- gravel.	{	Rounded and subangular flint-gravel in deep red sand, in buff-coloured paste, and at bottom in chocolate-coloured sand: bedding, where discernible, often twisted, sometimes nearly vertical	4	2
				7	6
Total superficial beds		7	6	

These rest upon the "soft sands" of the Bagshots of No. 3 type. The well here is 35 feet deep, and probably, like many of the wells hereabouts, does not go completely through No. 3 Bagshots, the water being held up by a pan in the sand, which is much preferred to going down into the "blue stuff." The water of this well is slightly chalybeate, but very good if not allowed to stagnate. It possesses considerable solvent action, I am inclined to think, on iron pipes, and has a very small solid residue on evaporation. Not long ago Mr. Gray, the principal well-sinker, whilst cleaning out one of the wells in the neighbourhood, had the misfortune to break the pan, when he forthwith lost all his water, and had to go many feet deeper before he got it again.

Railway-section near Haines' Bridge.—This is about $\frac{1}{2}$ mile further down the line than the end of Walton Common, and I went to inspect it on the 27th November, in order to make a rough com-

parison with the section already described. The superficial beds are still well developed, probably 14 feet, but the surface has been messed about so much that this estimate is given with reserve. The Lower Bagshots are still fine soft sands slightly laminated, but in the main resembling the No. 3 type. There is a considerable difference in the development of the Plateau-gravel. In the first place the erosion of the Bagshot surface is very slight—so slight, indeed, that I fancied at first that the gravels (*p* of fig. 7) were conformable and part of the Bagshot series. But closer inspection did not confirm that impression. Unless I am greatly mistaken, the basement-bed of the Plateau-gravel is a somewhat regularly bedded gravel series, but rather variable as to thickness. Certainly there

Fig. 7.—Section about 150 yards east of Haines' Bridge.



- Plateau-gravel. {
- m.* Chiefly sand with flints interspersed, a sandy phase of the ordinary Plateau-gravel.
 - n.* A sticky white loam, partly bedded, and rather of the nature of the lower beds of the Middle Bagshots of St. George's Hill.
 - o.* Coarsish brown sand, bedded, and with ferruginous layers.
 - p.* Flint-gravel with a large proportion of pebbles rather evenly bedded, not much sand.
 - b.* Lower Bagshots *in situ*.

are places where it seems quite to belong to the underlying Bagshot Sands, whilst there are others where the interpretation would be different. I ought to say that throughout the cutting I have never seen such a thing as a pebble in the Lower Bagshots. This should be mentioned, because in some places pebbles are stated to be abundant, though mostly perhaps in the Upper Bagshots. I should feel disposed to describe the section here as follows:—

The most curious feature here is the sticky white loam (*n*) which may be traced for a considerable distance on the left. Considering the mutable character of superficial deposits, the beds *p*, *o*, and *n* maintain themselves for some distance. In fact *p* seems to be nothing more than an unusually regular representative of the bedded

gravels, which are so frequently found at the base of the superficial beds on Walton Common. It must be borne in mind that Haines' Bridge is almost at the foot of the slope of St. George's Hill, on the top of which there is a large outlier of Middle Bagshots, and it is the wear of these, I imagine, which may have contributed to the formation of such a bed as *n*. There is nothing suggesting ice-action in this lower group, which seems to have preceded by some time the more confused and drift-like deposits overlying it, which were formed since *n* has been cut through, if one may judge from appearances. Hence at this point the Plateau-gravel is divisible into two series of slightly different age.

St. George's Hill.—It only remains to institute a comparison with the Plateau-gravel of St. George's Hill. The pit on the summit-level, or table-land, at present in work is situated about halfway between the north and south ends of the hill. This may be taken to represent an average sample of the most elevated sheet of gravel in the Weybridge district, and is probably about 250 feet above O.D. The longest face of the working is 45 yards, with a mean depth of a little under 9 feet. There is no "Top Sand" here, such as we have in Oatlands Park, only the upper part of the gravel becomes more sandy, as though the sand had worked up, and the flints had worked down rather—the wind, too, probably assisting this process, which seems very general in sandy gravels. The gravel rests on a slightly undulating surface. It is moderately sandy in places and includes a piece of argillaceous Middle Bagshots about a foot long. But the most striking feature in the section is a mass of brownish sand, 11 yards long and about 2 or 3 feet thick, occurring in the midst of the gravel in such a way as to suggest the idea that it had been floated bodily into that position.

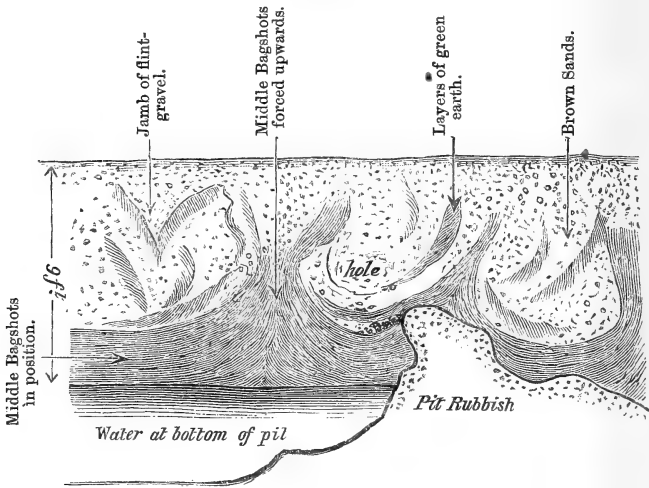
I think, however, that the strongest evidence of ice- or snow-action is to be found at the loam-pit on the north flank of St. George's Hill. It has before been stated that the two great gravel sheets of this district are (1) on the summit plateau, and (2) at the northern foot of St. George's Hill, the latter being, of course, what I have called the Walton-Oatlands sheet. It has also been stated that the *slopes* of St. George's Hill are clear of Plateau-gravel. But at the loam-pit there is a subordinate plateau or shelf just at the foot of the sharp rise which constitutes the final summit. This lies about 185 feet above O. D., and it contains a very interesting superficial deposit, which may fairly be ranked with the Plateau-gravel, although there is very little actual gravel in it.

Fig. 8 will serve to explain what I have called the "contorted series," as it is seen overlying the basement-beds of the Middle Bagshots at the place in question. The Middle Bagshots here consist of a buff laminated clay or clayey loam of a very tenacious character. The superficial beds are made up of green and brown sands and loams in a contorted arrangement mixed with tongues of the underlying pale buff laminated clays, which have been squeezed up in the manner represented; jambs of flint-gravel occur here and there, but not of large size; and flints generally are rather scarce.

Hence this deposit can only be called a "gravel" by courtesy. Specimens of the hardened beds of the Lower Greensand are of occasional occurrence.

Altogether this is an eminently local deposit, and seems to have been derived largely from the green sands and loams of the upper division of the Middle Bagshots, which ought to form the last 50 feet of St. George's Hill. It is not difficult to imagine that, when the climate was colder, the steep northern slope of St. George's Hill was occupied by a kind of *névé*, or a sliding mass of indurated snow. This, adhering to the green-sand beds, caused large masses of them to slide downwards, involving also a portion of the original plateau; hence the occasional jams of flint-gravel. That this was

Fig. 8.—*Contorted Series overlying Middle Bagshots, St. George's Hill.*



pushed over the clay beds of the Middle Bagshots is perfectly clear from the way in which these latter are squeezed up and involved in the superficial mass. At the same time we may admit that the contours are not quite the same now as when this deposit was formed, and that the deposit itself is merely a remnant of a much larger spread which may have occurred about this level.

Summary.—The section on the London and South-Western Railway above described shows:—

(1) That the "Top Sand" of Oatlands Park, in a modified form, extends at least as far as Walton Station, and covers the entire surface, though thicker over the Bagshot-Sand area than over the London-Clay area.

(2) That the valley-slope, west of Walton Station, consists of a curious mixture of gravel and clay, and that this "Mixed Series"

has relations with a long mass of yellow sand, the exact nature of which is somewhat doubtful.

(3) That the London Clay *in situ* appears very suddenly west of this mass of sand, and extends several hundred yards further to the westward than is shown on the Survey map (No. 8). In fact, as regards the line itself, the London Clay on this map is represented as terminating just where it should begin, *i. e.* about 320 yards west of Walton Station.

(4) That the Bagshot Beds near Sir Richard's Bridge succeed the London Clay unconformably, and that there is an argillaceous member of the basement series, which may be the same as the Ramsdell Clay of Mr. Whitaker.

(5) That the Plateau-gravel is abnormally thick towards the west end of the section, where the underlying Bagshots present irregular and deeply eroded surfaces; and that, in this region of its greatest development, something like three varieties may be distinguished, of which the middle one is the most sandy. The general composition of the Plateau-gravel of Walton Common and Oatlands Park bears out in the main the observations of previous authors.

(6) A comparison with other exposures in the neighbourhood serves to show the great variety of deposit which at present is classified under the head of "Plateau-gravel."

DISCUSSION.

Prof. PRESTWICH, speaking from memory of the original section, which he had examined when the railway line was being constructed, was inclined to argue more strongly than the author of the paper against the idea of there being an unconformity between the London Clay and the Lower Bagshot; nor could he find any distinct evidence of such unconformity in any other section in the district. He thought all the appearances described in the paper might be explained by a slight false-bedding, caused by the shoaling of the sea after the deposition of the London Clay, and the shifting and somewhat eroding currents of the shallower sea of the Lower Bagshot. He was, indeed, inclined, from recent observations which he had made, to regard the Lower Bagshot as the upper member of the London Clay. Although northern-drift rocks were not found in the Plateau-gravels of the district described by the author, yet such rocks were found at other points lower down the Thames in the same beds.

Prof. T. RUPERT JONES agreed with the author of the paper that the slight discordance in the dip looked like unconformity, but admitted, with Prof. Prestwich, that the appearance might be deceptive. He pointed out the extreme variability of the beds.

The Rev. A. IRVING agreed with the Author as to the distinctness of the bedding in the London Clay; but he differed from him as to the identity of the argillaceous bed at Walton-cutting with the Ramsdell beds of the Geological Survey. He thought the Ramsdell Clay belonged to the Middle and not to the Lower Bagshots. He

remarked on the common occurrence of "pans" in permeable beds near the surface. He thought the "mixed gravels" of the Author resembled in construction those found around the edges of many of the plateaux in the Bagshot district.

Mr. CLEMENT REID thought that contortion of beds, like that described by the Author, occurs in districts where no ice-action has taken place, and he suggested that they might be due to the movement of a soil-cap like that of the Falkland Islands.

Mr. MONCKTON had carefully examined all the sections where unconformity might be detected, and found himself quite unable to arrive at any certain conclusion on the subject. He doubted whether the variable clays described were entitled to be called Ramsdell Clay, a name originally applied to beds in the Newbury district.

Dr. G. J. HINDE was able to recognize among the pebbles from the Plateau-gravel, flints with Hexactinellid Sponges from the Chalk, and portions of hard sponge-beds from the Neocomian strata to the southward at Godalming and Hindhead.

Mr. J. STARKIE GARDNER had seen the section in question, and was strongly inclined to believe in an unconformity between the London Clay and the Lower Bagshot. The former, he thought, was marine, and the latter, in this particular section, freshwater and fluviatile, and therefore deposited at a much later date.

The AUTHOR agreed that the question of unconformability was a very difficult one to decide. He simply argued for unconformability on a small scale in this particular section. He thought that the fact of the Wimbledon gravels containing northern rocks was a proof of the difference of their age from the Oatlands gravel. He insisted on the difference between the London Clay and the argillaceous beds of the Bagshots. He did not insist on the identification of the clay at Walton with the Ramsdell Clay. He was inclined to agree with Mr. Clement Reid that the contorting of the beds, in the particular instance mentioned, was due either to a soil-cap or to moving masses of snow, though there were difficulties in accepting this interpretation.

12. *On the FOSSIL MAMMALIA of MARAGHA, in NORTH-WESTERN PERSIA.*
By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read January 27,
1886.)

THE fossil Mammalia of Maragha, a village situated some distance due south of Tabriz, in north-western Persia, have formed the subject of several notices by German writers, foremost among whom are Messrs. Grewingk *, Pohlig †, and Rodler ‡. As Dr. Pohlig, who has communicated a paper to the Society which will be read this evening, is, I believe, about to write a monograph on the Maragha Mammalia, I do not in any way wish to interfere with or unduly forestall his work; but since a collection of these remains has been sent to the British Museum by Mr. R. Damon, F.G.S., with a view to their being purchased by that institution, in which case it would fall to my lot to describe them in the Museum Catalogue, and since the specific determination of the Maragha Mammalia is a matter of considerable importance in relation to the western limits of the Siwalik fauna of India (the description of which I am just bringing to a conclusion), I have ventured to lay a few notes on the Maragha Mammals before the Society, and hope that my German *confrères* will regard them as an endeavour to assist, rather than to mar their work.

Dr. Grewingk, in the paper cited, recorded the following forms, viz. :—*Helladotherium*, sp., *Tragoceros*, sp., *Bison bonasus*, *Cervus elaphus*, *Equus caballus*, *E. onager*, *Hipparion*, sp., *Rhinoceros antiquitatis* §, *R.* sp., *Elephas primigenius*, and *Mastodon* (?), sp. It was left an open question whether the existing and Pleistocene forms were contemporaries of the others; but it was concluded that the older forms indicated the representatives of the Lower Pliocene Pikermi beds. Dr. Pohlig mentioned *Tragoceros* and other large antelopes, *Cervus* and allied forms, *Hipparion* and perhaps another small equine, *Rhinoceros* or *Aceratherium*, *Elephas* or *Mastodon*, and an *Hyaena* which was thought to be probably identical with the Pikermi *H. eximia*. Dr. Rodler, in addition to the forms already mentioned, recorded the Pikermi *Gazella deperdita* ||, and *Palæoreas Lindermayeri*, as well as species of *Antidorcas* and *Sus*. He identified the *Hipparion* with *H. gracile*, and considered that an *Equus* and probably a species of *Elephas* occurred in the same beds. The typical Maragha fauna was regarded as of Pliocene age; but the existence of an associated Pleistocene fauna was considered as not improbable. To the above-mentioned Pikermi forms the specimens sent to the British Museum apparently add *Giraffa attica* ¶ and *Palæoryx Pallasii*; and they also indicate that the *Sus* is apparently *S. erymanthius*, the *Mastodon* is *M. pentelici*, and the

* Verh. k.-k. geol. Reichsanst. 1881, p. 296.

† *Ibid.* 1884, pp. 281–284.

‡ *Ibid.* 1885, no. 14, p. 333.

§ Syn. *R. tichorhinus*.

|| Syn. *G. brevicornis*.

¶ Syn. *Camelopardalis attica*.

Helladotherium, *H. Duvernoyi* (which is probably common to the Pikermi beds and the Siwaliks *), while they confirm the suggested identity of the *Hyæna* with *H. eximia*. They point moreover to the presence of *Felis brevirostris* of the Upper Pliocene of the Auvergne; to a species of *Rhinoceros* (which may or may not be identical with the one identified by Dr. Grewingk with *R. antiquitatis*) apparently intermediate between *R. antiquitatis* and the Siwalik *R. platyrhinus*, which is not improbably an ancestral form of the former; and also to *R. Blanfordi* †, which was first recorded by myself ‡ from the north-western frontier of India §, and has been subsequently described by Dr. Ernst Koken || from the (probably) Pliocene of southern China, where it occurs in association with *Mastodon*, *Tapirus*, *Hipparion*, *Chalicotherium*, *Giraffa*, *Hyæna*, &c. This last species appears, therefore, to have ranged from north-western Persia through Baluchistan, the Punjab, and thence, probably *viâ* Tibet ¶, to China.

From strata of unknown age at Erzerum, in Armenia, Dr. Falconer many years ago described some elephant molars under the name of *Elephas armeniacus*; and as Erzerum is comparatively near to Tabriz, it may be suggested that some of the Maragha elephants' teeth may not improbably belong to this species; but be this as it may, the Erzerum and Maragha faunas may be geographically grouped together. There is in the British Museum an elephant's molar from China (No. 29007), which has been suggested to belong to this species; and if this were correct it would seem that the range of *E. armeniacus* was somewhat the same as that of *Rhinoceros Blanfordi*, *i. e.* that it extended from western Asia through the regions lying to the north of India to China; I am, however, disposed to refer the specimen to *E. namadicus*. The structure of the molars of *E. armeniacus* is such that this species might well have been an ancestral form allied to both *E. primigenius* and *E. indicus*; and its geographical distribution is such as to harmonize with this view.

Putting aside on the present occasion the Pleistocene and existing species recorded by Dr. Grewingk from Maragha, the majority of the other members of the Maragha fauna agree so closely with the fauna of the Pikermi beds that there can be no hesitation in adopting the views of the German palæontologists as to the one fauna being the representative of the other. The occurrence, however, of *Felis brevirostris* in the Maragha beds, coupled with the suggestion that *Elephas armeniacus* may also be found there, together with the now well-ascertained fact that the older mammalian types survived in Asia long after they had disappeared from Europe, renders it not

* See 'Cat. Foss. Mamm. Brit. Mus.' pt. ii. p. 71 (1885).

† Syn. *Aceratherium Blanfordi*; I propose for the future to include *Aceratherium* in *Rhinoceros*.

‡ Palæontologia Indica, ser. 10, vol. iii. p. 2 (1884).

§ Dera Búgti in Baluchistan, and the Búgti Hills to the north of Jacobabad in Sind.

|| Pal. Abhandl. vol. iii. pt. 2, p. 18 (1885).

¶ This may be the *Rhinoceros* recorded by Falconer and Cautley from Húndes in Western Tibet.

improbable that the age of the Maragha beds may be somewhat later than the Lower Pliocene. This suggestion is perhaps confirmed by the occurrence at Maragha of *Rhinoceros Blanfordi*, which, in Baluchistan and Northern Sind is met with in the Lower Siwaliks, accompanied by a variety of *Mastodon angustidens* (characteristic of the Middle Miocene of Europe), *Hyopotamus*, and *Anthracotherium*, the age of the Lower Siwaliks being certainly not later than the Upper Miocene, and not improbably being Lower Pliocene. As the accompanying older forms are apparently not found at Maragha or in the Pliocene of northern China, where *R. Blanfordi* is again met with, it is most probable that the Maragha beds are of later age than the Lower Siwaliks.

One of the most interesting and important points connected with the Maragha deposits is the proof afforded that the Pikermi fauna, which has been traced as far northwards as Hungary, extended to the north-western extremity of Persia, where it came in contact with one member of the extreme western branch of the Siwalik fauna of India, which branch differs widely from the more eastern portion of that fauna, and exhibits a much more strongly marked Palæarctic *facies*. The same member (*Rhinoceros Blanfordi*) connects the Erzerum-Maragha fauna with that of northern China, which is known to be in great part Oriental (Siwalik), and will not improbably prove to be in part Palæarctic. The apparent occurrence of the Pikermi species of *Helladotherium* at Maragha is important as confirming the provisional identification of the Siwalik species of that genus with the former. Another feature calling for especial notice is (with the foregoing exception) the apparent absence of eastern Siwalik forms from the Maragha fauna; and although subsequent finds may, and very probably will, bring to light some common forms*, yet this absence appears to be so marked that it seems to suggest that even in Pliocene times there was a decided division, so far as species are concerned, between the faunas of the Palæarctic and Oriental regions, where the two came in contact on the north-western frontier of India. If this view be borne out by future observations, it would further suggest that some of those genera at present characteristic of the Ethiopian region which are found in the Siwaliks and are at present unknown elsewhere (*e.g.* *Cynocephalus* †, *Alcelaphus* ‡, and apparently *Strepsiceros* §, *Hippotragus* ||, and *Cobus* ¶) did not make their way into Africa *viâ* northern Persia and Syria, but may have passed through southern Baluchistan and Persia, and thence across the gulfs of Oman and Aden, on a line connecting the present Oriental and Ethiopian regions. Other modern Ethiopian genera, however, like *Giraffa* and *Hippopotamus*, are known to have ranged over the northern Oriental and the southern Palæarctic regions in

* The apparent affinity of *Mastodon pentelici* to the western Siwalik *M. pandionis* is very noteworthy; but adult molars of the former are required before their full affinity can be determined.

† See 'Cat. Foss. Mamm. Brit. Mus.' pt. i. p. 4 (1885).

‡ *Ibid.* pt. ii. pp. 55, 56 (1885).

§ *Ibid.* p. 47.

|| *Ibid.* p. 49.

¶ *Ibid.* pp. 53, 54.

Pliocene and Pleistocene times, while the distribution of *Struthio* may be traced almost continuously from the Siwaliks, through Baluchistan and Persia, to Syria and Africa*. The suggested relation of the Erzerum-Maragha fauna (through the unnamed *Rhinoceros*) with the Pleistocene fauna of the northern Palæartic region, and (through *Elephas armeniacus*) with the existing Oriental fauna, have been already discussed; and the writer concludes this notice of the Erzerum-Maragha fauna with the expression of the hope that the labours of the German palæontologists will reveal more fully the relations between the Pliocene fauna of the Palæartic and Oriental regions which the Maragha deposits give promise of illustrating.

For the discussion on this paper see p. 181.

* See 'Palæontologia Indica,' ser. 10, vol. iii. p. xxiv. (1886).

13. *On the Pliocene of Maragha, Persia, and its Resemblance to that of Pikermi in Greece; on Fossil Elephant Remains of Caucasia and Persia; and on the Results of a Monograph of the Fossil Elephants of Germany and Italy.* By Dr. H. Pohl. (Communicated by Dr. G. J. Hinde, F.G.S.) (Read January 27, 1886.)

I.

IN 1884 I had the opportunity of making a geological tour in Persia, especially in the northern provinces, one of my principal objects being to excavate a deposit of Pliocene mammals discovered about 30 years ago by the Russian travellers Göbel and Khanikoff near Maragha, to the east of the lake of Urumia. Abich, Brandt, and Grewingk* have already published short notes upon the subject, but the locality where these fossil bones were found has not been exactly specified.

Arrived at Maragha I found several deposits of fossil bones, and excavated them as long as the season permitted. The results obtained I first announced in two letters sent from Maragha to Prof. von Lasaulx † and to Dr. Tietze ‡, including a preliminary list of the Pliocene mammals of Maragha which had been obtained up to that time, and so far as I could determine them on the spot without means of comparison. The collections made by me in Persia are now mostly deposited in the Museum of Prof. von Fritsch at Halle.

In the course of last year a young German residing in Persia successfully continued my excavations at Maragha, and it was a portion of the bones collected by him that M. Gaudry saw in the Museum at Vienna (see *Geol. Mag.* December 1885, p. 558).

As I am now engaged in preparing a monograph on the fossil mammals of Maragha, I wish in this paper to give a sketch of the deposits containing these remains and also a supplement to the list already published.

The Maragha valley owes its origin to a wide fissure of dislocation traversing in an equatorial direction the chain of Cretaceous (and Jurassic?) mountains bordering the great lake of Urumia on the east. Through that fissure the waters coming from the north-east, from the volcanic mountains of Sahend covered with snow, in Pliocene times already flowed into the Urumia lake, which was much higher then than now. At this time the valley of which Maragha is the centre was an inlet of the lake, traversed by the rapid streams flowing from the Sahend. Hence the Pliocene deposits of Maragha are of fluvio-lacustrine origin, like those of Pikermi, near Athens, with which I was able to compare them directly on my return journey from Persia, and like those of the Val d'Arno, near Florence, which I had previously visited.

* *Verhandl. k.k. geol. Reichsanst.* 1881, p. 296.

† *Verhandl. Naturh. Ver. d. preuss. Rheinl.* 1884, *Sitzungsb.* p. 174.

‡ *Verhandl. k.k. geol. Reichsanst.* 1884, p. 282.

The constitution of the Maragha Pliocene is very similar to that of the Pikermi beds, consisting of pale reddish marls, which are very hard below, but loose at the surface, with singular forms of erosion; they are the detritus of the volcanic ashes and tuffs of the Sahend, and accumulations of pumice stones are frequently found in them, usually associated with the bone-beds. The marls also contain numerous more or less considerable strata of pebbles, the *débris* of the Sahend rocks, and these are sometimes of respectable dimensions, up to more than 1 metre in diameter. Nearest to the Sahend the pebble-beds prevail, and the boulders are still larger, the whole being closely connected with the vast chaos formed by the erratic blocks of the earliest Pleistocene deposits. The intimate relation between the Pliocene and Pleistocene in Persia corresponds well with the correlations of the two groups in Europe, as on the Norfolk coast and in many other localities. The general form of the Pliocene hills of Maragha produced by Pleistocene erosion is that of table-mountains, seldom conical. Several small reefs of Cretaceous rocks penetrate the equally horizontal beds of the reddish marls, forming elevated banks. The Pliocene hills environing the town rise to more than 100 metres above the level of the torrent Safi-chahi, which passes close to Maragha.

The fossil bones have been found in the reddish marls at more than six places, at greater or less distances from the city (up to 30 miles), and at different horizons, which, however, do not differ from each other by any characteristics of the mammalian fauna.

The list of the Maragha Pliocene mammals formerly given by me may now be completed as follows:—

1. *Hipparion gracile*. Several complete skulls, with the mandibles, and nearly all the bones of the skeleton. This is the commonest form in the Maragha Pliocene.

2. *Onager*? sp. A smaller species of Equidæ.

3. *Rhinoceros persiæ*, Pohlig. Species with incisors, but otherwise closely allied to *R. tichorhinus*; this is also very common at Maragha*, no fewer than four adult skulls, another with the milk-teeth &c., having been found.

[3 a. *Rh. Blanfordi*, Lyd., according to Lydekker.]

4. *Mastodon*, sp. Less common. A tusk of this genus had a maximum length of 2·35 metres.

5. *Sus*, sp.

6. *Gazella brevicornis*.

7. *Palæoreas*, sp.

8. *Tragoceros*, sp. Allied to the Pikermi species. Very common in the Pliocene of Maragha.

9. *Antilope*, sp. *major* (*Antidorcas*?).

10. *Bubalus*? sp.

11. *Cervus*? sp.

* The occurrence of remains of large herbivorous animals in the Maragha Pliocene proves the occurrence of an abundant vegetation at that period on the Persian highlands, now so barren where not artificially irrigated.

12. *Helladotherium*, sp. Probably the same as at Pikermi.
 [13. *Giraffa attica*
 14. *Felis brevirostris*] according to Lydekker.]
 15. *Hyæna*, cf. *eximia*.
 16. *Canis*? sp.*

The list will doubtless be increased by material recently received.

As regards the remains of Pleistocene and cave-mammals (such as *Rhinoceros tichorhinus*, *Hyæna spelæa*, &c.) cited by Brandt and Grewingk as coming from Maragha according to the reports of Göbel and Khanikoff, no traces of them have been found either by myself or my successor. It is true that there are several caverns or grottos in the environs of the city, but they are labyrinths or chambers made artificially in the compact marls or in the volcanic tuffs of the Pliocene; it seems to me therefore that a Pleistocene fauna does not really occur in the Maragha valley, and that its supposed presence must be founded upon some confusion in the statements of Russian travellers.

II.

In the same journey I visited the Caucasian Museum at Tiflis and found in it several fossil remains of Elephants from both sides of the chain of the Caucasus. For the most part they are remains of the true Mammoth (*Elephas primigenius*, Blum.), so that it is evident that that cosmopolitan monster passed over the high Caucasus as well as, in Europe, the Alps and Pyrenees; this is interesting also with regard to the so-called *E. armeniacus* of Falconer, found at Erzeroum.

The Tiflis museum contains a last true molar of *E. primigenius* from the Sundsha river, north of the Caucasus; it is the broadest proboscidian molar hitherto found, having an extreme breadth of 0.13 to 0.14 metre. From Daghestan, in Transcaucasia, there is, among others, an *os innominatum* of *E. primigenius*, having a very typical foramen ovale of 0.195 × 0.1 metre; and a large calcaneum, of 0.27 × 0.19 metre was found at Alexandropol, at an altitude of 5000 feet. There are also some very heavy bones and fragments of molars from the Kuban river, north of the Caucasus; the molars have the characters of those of *E. meridionalis*, Nesti, containing three ridges in 0.05 metre of the length of the crown.

In the preceding section I have already recorded the fossil remains of Proboscidia found in the Maragha Pliocene. At Teheran I heard that Dr. Tholozan, physician to the Shah, possessed fossil Elephant remains found in Persia; unfortunately he was absent at the time, but he has since written to me that he has a fossil elephant's tooth (*E. primigenius*) from Radechane in Khorassan.

* The state of preservation of these bones is very similar to that of those from Pikermi; they are generally white, sometimes reddened by the marls containing them, and rendered very heavy by the presence in them of a considerable amount of vivianite.

III.

The collections of Pleistocene mammals in German and Italian museums being very rich and generally but little known, I resolved to examine them with the view of preparing a general memoir. For this purpose I worked in the museums of Munich, Jena, Halle, Dresden, Leipzig, Stuttgart, Karlsruhe, Mannheim, Darmstadt, Frankfort, Wiesbaden, Bonn, and Münster, in Germany; in those of Verona, Padua, Bologna, Florence, Rome, Pisa, Genoa, Milan, and Turin, in Italy; and I also studied in the museums of Lyons, Brussels, and Tiflis, and in several private collections. For the same purpose I visited the museums of London, Paris, Leyden, Berlin, Prague, Brunn, Vienna, and Odessa; and in the coming spring I intend visiting the collections in Spain and Portugal.

I have commenced with a monograph of the German and Italian fossil Elephants, the first part of which, embracing the dentition and craniology, is now completed, and the principal results of that work are as follows:—

1. *Elephas antiquus*, Falc., was the largest of all terrestrial mammals hitherto known. One of the most remarkable peculiarities of that species is the extreme divergence of its incisor alveoli, amounting to about 1 metre. In craniology, as in dentition, *E. antiquus* has several relations with *E. africanus*.

2. The pigmy insular fossil races of the Mediterranean (Malta &c.) cannot be considered specifically distinct from *E. antiquus*; we must rather regard them as several gradations of a diminutive race of that species produced by degeneration, and designate them *E. (antiquus) melitæ*, Falc.

3. *Elephas meridionalis*, Nesti, emend. Pohl., did not quite attain the dimensions of *E. antiquus**, and differs widely from the latter in dentition and craniology. The opinions published by Nesti and Falconer on this species, as also their figures, are incorrect in several points, and will be amended in my monograph. The skull of *E. meridionalis* presents several resemblances to that of *E. indicus*, and especially to that of *E. primigenius*.

4. The fossil remains from the Siwalik hills figured by Falconer and Cautley under the name of "*E. hysudricus*" can no longer be regarded as distinct from *E. meridionalis*, in accordance with the emendations of the latter species made in my monograph.

5. The knowledge of *Elephas primigenius*, Blum., has also been considerably augmented by the description and representation of a vast series not hitherto published. In dimensions the Mammoth was

* In the discussion on the present paper (see page 181) Messrs. Boyd Dawkins and Lydekker seem to have been uncertain as to the sense in which I understand the names *E. antiquus* and *E. meridionalis*; I understand them in the usual manner, as that of Nesti, Falconer, and L. Adams, but excepting about one tenth of the specimens of these authors, and, as regards *E. antiquus*, adding the enormous continental series hitherto unknown. The above statements are not mere *theses*, but facts, proved in my monograph by numerous admeasurements and numbers, attained by a study of nearly seven years, but which it is impossible to repeat here.

inferior to *E. meridionalis*, and still more to *E. antiquus*. The pigmy forms existing of *E. primigenius*, as well as of *E. antiquus*, have partially or entirely lost the characters of a distinct local race, having anew communicated with the primitive form over a wide territory. The Mammoth is most nearly allied to the existing Indian species, but nevertheless it is quite distinct specifically from the latter.

6. Under the name of *Elephas trogontherii*, Pohlig, I have described European molars which hold a middle place, both zoologically and geologically, between those of *E. primigenius* and *E. meridionalis*, most closely approaching those of *E. antiquus* in the ridge-formula, but differing more from them than from the other two in the form of the crown. The position of *E. trogontherii* with regard to *E. armeniacus*, Falc., and *E. namadicus*, Falc., still remains to be investigated. In craniology and dentition *E. meridionalis* and *E. primigenius* are directly allied by *E. trogontherii*.

7. The supposition of a "præantepenultimus" in the milk-molar series inferred by Falconer and Leith Adams, has no foundation.

8. I distribute the Elephants, in accordance with the forms of the tooth-crowns and the ridge-formulæ, into:—

ARCHIDISCODONTS (*E. planifrons*, *meridionalis*); LOXODONTS (*E. africanus*, ? *antiquus*); and POLYDISCODONTS; (*E. primigenius*, *indicus*, &c.); arranging the Stegodonts, like Clift, with *Mastodon*.

DISCUSSION.

Prof. W. BOYD DAWKINS referred to the difficulty of discussing species from names only without seeing the specimens. With regard to Mr. Lydekker's paper he said that the Maragha mammalia belonged to the same fauna as those of Pikermi, and that it was interesting to find them occurring so far to the east. He felt doubtful, however, whether they belonged to the Pliocene, which is always defined by the appearance of a few living species of the higher mammalia among the extinct species. There are no living mammals in Prof. Pohlig's list. He stated that he is at present engaged in the examination of a large collection formed by Mr. Calvert in the Troad, and this he found to contain Giraffes, Mastodons, and Hipparions identical with Pikermi forms. This discovery connected the find in Attica with that near the Caspian. The speaker agreed with Prof. Gaudry in regarding this deposit as Upper Miocene rather than Lower Pliocene. The occurrence at Maragha of Rhinoceroses with low crowns, like *R. Schleiermacheri*, which are Miocene in France and Spain, seemed to be conclusive upon this point, as that form is Lower Miocene. The absence of the genus *Elephas* was also of importance. Mr. Lydekker had mentioned the *Hypopotamus*. This animal is found only in the Lower Miocene deposits of Europe and America, and it has not as yet been found in association with any animals belonging to the same fauna as that of Pikermi.

Prof. Boyd Dawkins further remarked that in his paper Prof. Pohlig had pointed out distinctions between different species of Elephants. The speaker thought that the Pigmy Elephants of Malta, Corinth, &c. cannot be considered forms of *E. antiquus*. Nor could he agree with Prof. Pohlig's statement as to *E. meridionalis*. Especially he was not prepared to admit that *E. antiquus* was the largest of the Elephants, and he thought that any one who had seen the specimen of *E. meridionalis* from the south of France which had been set up by Prof. Gaudry in the Museum of the Jardin des Plantes, would agree with him. At the same time he admitted that further information was necessary before criticizing Prof. Pohlig's remarks.

Mr. LYDEKKER observed that he was glad to find that his own views as to the Maragha species accorded in the main with those of Dr. Pohlig, although he thought it probable that the form named *Rhinoceros persie* was really *R. Blanfordi*. With regard to the Elephants, it appeared to him almost as though Dr. Pohlig had reversed the application of the names *E. meridionalis* and *E. antiquus*. In connection with the proposed identification of the Euelephine *E. hysudicus* with one of the European species (*E. meridionalis*, Pohlig), he should observe that Leith Adams had proposed to identify *E. antiquus* with *E. namadicus*, and that the affinity of *E. hysudicus* appeared decidedly nearer to the latter than to the Val d'Arno Elephant. Neither was he prepared to accept the proposed identification of *E. melitensis* with one of the larger European species. The reversion to Clift's association of the stegodonts with *Mastodon* appeared to be a retrograde proposal. In reply to Prof. Boyd Dawkins, he pointed out that the age of the Pikermi beds has been determined by Pliocene molluscs being found in the lowest of them. He therefore classed both Pikermi and Maragha as Pliocene. The case of *Hyopotamus* was as follows:—It occurs in Beluchistan with *Rhinoceros Blanfordi*, in beds overlying others, the age of which has been shown by Prof. Duncan, from the examination of the Echinodermata and corals, to be Upper Miocene.

14. *On the ALTERATION of COARSELY SPHERULITIC ROCKS.* By
GRENVILLE A. J. COLE, Esq., F.G.S. (Read March 10, 1886.)

[PLATE IX.]

As has been previously stated*, all the phenomena that accompany spherulitic structure on an ordinary scale appear reproduced among lavas that may be called coarsely spherulitic. Ill-defined segregations, differing little from the matrix, the fluidal and banded structures of the rock running indifferently through both, are found measuring an inch or two in diameter, equally with forms of marked radial or concentric character. The scale on which certain processes of decomposition and reconstruction, especially those that affect differently the spherulite and the matrix, are revealed in these bold examples, and the interest attaching to their effect upon the ultimate character of the mass, have led me to bring together a few observations on the alteration of coarsely spherulitic rocks. Some of the finest instances, moreover, may be found in our own British lava-flows of Palæozoic age, and with these the field-worker is not unfrequently called upon to deal.

The well-known black pitchstone of Planitz, near Zwickau in Saxony, which is of Permian age, contains angular aggregates of calcite and chalcedony enclosed in large brown nodules. These remarkable occurrences were referred to by Cotta as early as 1849†, and his figure was copied by Delesse in a comprehensive paper on "Les Roches globuleuses"‡. Cotta considered the nodules surrounding the chalcedony as inclusions of an adjoining porphyry, like those in the pitchstone of Spechthausen; but the microscope proves them to be in reality large brown spherulites, often 3 centims. in diameter, and differing only slightly from the glass. Why the agents of alteration should have attacked them in so marked a degree is indeed a puzzling matter, which will be best solved by a study of the "Lithophysen" of more recent lavas; but there can be little doubt that these spherules were once solid to the core. Since they have no internal radial or concentric structure, the decomposition has hollowed them out irregularly, or has started along and spread from any cracks that might occur. The relation of the shape of the cavity so formed to these preexisting cracks may often be seen at the angular ends of its branches. The hollow has ultimately been filled with chalcedony or with calcite, which may also be found in cracks throughout the rock. There is no sign of a central mineral nucleus from which this material might have been derived, since the lines of flow throughout the nodule do not bend round as when an obstacle is present, but may be connected up with one another straight across the branchings of the secondary mass. The same evidence strongly opposes the supposition of the former existence of

* Q. J. G. S. vol. xli. pp. 165, 166.

† Leitfaden und Vademecum der Geognosie, p. 76.

‡ Mémoires de la Soc. géol. de France, 2me série, tome iv. p. 315.

a central vesicle, produced by the expansion of gases while the lava was still cooling down (Pl. IX. fig. 1).

An experiment as to the degree of solubility in acid of the spherulite and the matrix respectively yielded only an unsatisfactory result. Equal quantities of the powdered substances gave, after eight days' immersion, with two boilings, in strong hydrochloric acid, the following percentages of material dissolved :—

Glassy matrix.	Spherulite.
7·57	8·80

Although the portions of the spherulite were chosen with great care, some of the above difference might be due to minute included veins of calcite. On the other hand it is possible that even such a slight variation in behaviour as that indicated above might be greatly intensified by the temperature, and perhaps pressure, at which the natural solvents worked.

Angular secondary aggregates, apparently very similar to those of Zwickau, occur in other Saxon porphyries and pitchstones, and are recorded, as one might expect, from the most highly altered zones*. These igneous sheets are associated with Rothliegende sandstones and conglomerates, which are sometimes cemented by silica, sometimes by carbonate of lime, and which contain occasional calcareous layers; when, therefore, the felsitic spherules had once been hollowed out (a process begun, in all likelihood, while the volcanic centre was still active), the calcite and chalcedony may easily have infiltrated from the surrounding sedimentary rocks.

The process of secondary devitrification† tends often to lessen still further the difference between the spherulites and the matrix; so that we may at any time be confronted by an altered lava containing angular shreds of quartz, chalcedony, &c., which, had we none of the intervening stages, might even be regarded as fragments picked up during flow.

The red rocks of the Wrockwardine (Wrekin) area have preserved their original structures well; but among them is a coarsely spherulitic layer in which the formation of secondary quartz-masses has in places gone to an extreme. As in the historic Zwickau pitchstone and many later examples, the banding often traverses the larger spherules and carries trains of small ones through them. The largest spherulites are sometimes aggregates of those of medium size, and become, indeed, in this way elongate, knotty, or irregular. The development of quartz in their interior has been previously described‡; but I confess that on recently revisiting the area, I was unprepared for the scale on which this alteration has taken place. One spheroidal mass, for example, measures 11 centim. ($4\frac{1}{4}$ inches) in diameter, and yet the residual red material is often not more

* Lehmann and Siegert. Erläuterungen zur geol. Karte des Königr. Sachsen, Section Hohenstein, pp. 44, 45, & 53.

† See Bonney, Proc. Geol. Soc. 1885, p. 87.

‡ Q. J. G. S. vol. xli. p. 167. Cf. Monteiro, "Description minéralogique du Pyroméride globale de Corse." Journal des Mines, tome xxxv. (1814), p. 351.

than 1 centim., and in places a bare 3 millim. in thickness. The hollow shell thus formed by decomposition is now entirely filled with quartz; and it is, indeed, questionable whether this relatively large cavity ever existed as a whole, it being perhaps the result of successive excavation and infiltration.

Seen in section, the rock is often traversed by rudely parallel cracks, some of which are posterior even to the infilling of the hollows of the altered spherulites. These cracks, filled with chalcidony, are remarkably wide wherever they traverse spherulitic matter, but become mere lines, for the most part, while passing through the matrix. Nor is this due to their being disguised by the secondary devitrification of the glass*, since the perlitic curves across which they occasionally run exhibit no such break as a wider fissure would have caused (Pl. IX. fig. 2). If, as is highly probable, the variation in width of these cracks has been determined by decomposition along their walls, their sudden expansion when they enter even the smaller spherulites is somewhat striking evidence of the greater stability of the matrix, and would lead us rightly to infer that the agents which excavate cavities in such rocks would produce a marked effect on the spherulites alone †.

The rocks of Saxony and the Wrekin area prepare us, then, for finding a mass composed of great nodules of quartz, each enclosed in a felsitic envelope, the products of alteration being thus out of all proportion to such primary structures as remain. As we have on a small scale spherulitic rocks in which the segregations outcrowd the matrix, so we have in the Silurian rhyolite of Digoed ‡, near Penmachno, a mass some 15 feet thick, consisting almost entirely of white close-set nodules. These reach 7 or 8 centim. (3 inches) in diameter, and are almost all filled with quartz, the outermost layer of the spherulite being often alone preserved. A chloritic mineral is generally associated with the quartz (Pl. IX. fig. 3). Here and there the spherules suddenly diminish in size until their exceptional character is lost, while the matrix for a short interval assumes its normal predominance. Prof. Bonney §, to whose detailed investigation and description of North-Welsh nodular felsites students of this area must always turn, has referred to this rock in connexion with similar

* The product of this devitrification seems very largely to be felspar, twinning even being exhibited by many of the granules. Cf. Bonney, Proc. Geol. Soc. 1885, p. 94.

† It may be worth while to state the exact position of the quarry where the best specimens of the Lea Rock lavas seem always to have been obtained, since there are few excavations in the area. The road from Wellington joins the main Shrewsbury road at a point called "Hay Gate" on the 1-inch Ordnance Map. $1\frac{1}{4}$ mile west of this is a toll-house, marked T. P., on the left. A large new red mansion lies a little further on upon the right, and beyond its lodge is a small cross road. The left hand or southern portion leads at once into the quarry. The name Lea Rock does not now seem to be recognized in the district.

‡ The farm of Digoed is found on the 1-inch Ordnance Map by following the high road south-south-east from Bettws-y-Coed till a branch goes off to Penmachno above the Conwy Falls. Digoed is set high on the east side of this branch, about 1 mile towards Penmachno, and the nodular rock rises in one or two bosses near the house.

§ Q. J. G. S. vol. xxxviii. p. 289.

examples from the neighbourhood of Bettws-y-Coed. It is interesting also to find that, before 1852, Delesse * examined at Jermyn Street certain nodular specimens from Llanberis and Digoed †, and classed them accurately with the "globular porphyries" and pyromerides of many foreign localities. The beautiful plates, drawn from polished surfaces of large and altered spherulites, that accompany his descriptions are monuments of faithful and minute work done when section-grinding was unknown.

In spite of their great size, the material of which the spherules of Digoed are constructed appears to have been very finely granular, and perhaps almost glassy. The relics of an often minutely curving flow-structure ‡, and the occurrence of small crystals of felspar scattered here and there, recall the features of the large spherulites of Zwickau. But alteration has sometimes revealed an original concentric structure, the secondary quartz occupying only the alternate zones. In one of these cases there is beautiful evidence of the pressure and strain § to which this rock has been subjected even since the deposition of the secondary material. A series of parallel bands of liquid-enclosures, containing moving bubbles, has been developed in a curved zone of granular quartz; these bands pass continuously from grain to grain, and are reproduced on opposite sides of the dull grey centre of the nodule, being thus clearly due to one common cause, which has left no mark upon the felsitic zones (Pl. IX. figs. 4 & 5).

Ample signs of attempts to crush and cleave the rock are seen, however, in the compression of the spherulites and sometimes in the irregularly fissile character of the matrix, where it can be said to be truly present. A cleavage has been also set up here and there in a black alteration-product which occurs within the spherules, and which, from its striking contrast to the hard, white, highly silicated rock, has seemed to me to merit peculiar notice.

Prof. Bonney, in the paper referred to ||, has mentioned a dull flinty-looking, but soft substance as occurring among the secondary minerals in felsites near Bettws-y-Coed and on the Conway Mountain. In the rock of the latter locality the dark patches formed by it are unusually abundant, and their relation to the zones of alteration in the nodules is often beautifully seen. One flattened spherulite, measuring 18 millimetres in its longest diameter, consists of at least thirty concentric coats, half of them being converted into the black material. The wavy structure seen in the latter, under the microscope, seems, from its general persistence of direction in the different zones, to be due to an attempt at cleavage which has been resisted by the less yielding portions of the rock (Pl. IX. fig. 6).

At Digoed this dark substance occurs on a coarser scale, so as to

* "Recherches sur les Roches globuleuses." Mémoires de la Soc. géol. de France, 2me série, tome iv. (1852), pp. 315 and 327.

† These specimens may be seen in the rock-room of the Geological Survey Museum, numbered 382, &c., in the 3rd edition of the Catalogue.

‡ Cf. Bonney, Q. J. G. S. vol. xxxviii. p. 294.

§ See Judd, Q. J. G. S. vol. xli. p. 376.

|| Q. J. G. S. vol. xxxviii. pp. 290, 293.

resemble fragments of included slate, still showing a relation to the curving zones of the great spherules. Its origin is, however, much better indicated by the Conway specimens.

With a specific gravity of 2.77*, a hardness of about 2.5, and all the appearance of a metamorphosed clay, it became interesting to compare this decomposition-product with the parent rock. I suspect that the composition of both varies somewhat in different specimens, especially in the matter of silica, which is so largely accumulated in the cavities of the rock. The portion of the white matrix and spheroidal matter chosen was, so far as could be seen, free from secondary quartz; but the high percentage of silica shown probably over-represents its original proportion in the lava-flow.

	I.	II.	III.
	White spherulitic rock of Digoed.	Black layer in large spherulite, Digoed.	Average of six analyses of pinite (the extreme per- centages made use of are placed in brackets).
SiO ₂	83.08	50.75	47.8 (44.7-54.6)
Al ₂ O ₃	10.25	28.34	29.9 (23.6-32.4)
Fe ₂ O ₃	trace	3.63	5.7 (0.9-10.2)
CaO .....	.26	2.57	.7 (0.0- 2.4)
MgO .....	.09	1.85	1.8 (0.0- 3.4)
K ₂ O	1.78	6.21	8.7 (6.5-11.2)
Na ₂ O	3.58	2.19	.5 (0.0- 1.1)
Loss on ignition ..	.74	4.37	5.1 (1.2- 7.8)
	<hr/> 99.78	<hr/> 99.91	<hr/> 100.2

I have placed in a third column the average of six analyses of pinite quoted by Rammelsberg †. It will be seen that the figures of the second column generally fall within the extremes made use of in calculating those of column III., the main difference being in the proportions of the alkalis.

The alteration-product of Digoed (and, by inference, the black material of the other ancient rhyolites) seems, then, to be related to the substances of the pinite group, and has probably as little claim as they to be regarded as a mineral species.

Under the higher powers of the microscope, moreover, it is seen to be composed of particles of various kinds. In one nodule from Digoed it has given rise to minute crystalline tufts and bunches of a uniform character ‡, interspersed with secondary quartz (Pl. IX. fig. 7); but a large section of the fragment used for the analysis consists mainly of transparent angular grains of a very pale blue-green

* The specific gravity of the white matrix rises as high as 2.67, but is variable through included quartz.

† Handbuch der Mineralchemie (2nd edit.), Band ii. p. 656.

‡ The substance discussed by Kalkowsky ("Untersuch. von Felsiten und Pechsteinen Sachsens," Tscherm. Mittheil. 1874, p. 46) may perhaps be of a similar nature.

tint, averaging .01 of a millimetre in diameter, together with a number of minute greenish prisms, which give vivid colours under crossed nicols. The latter are probably pyroxenic.

The results of the foregoing observations may be briefly summarized. Leaving out of count the matter added to an altered spherulitic rock by infiltration, such as the quartz which has, in lavas above the Conwy Falls, produced veins some six or seven inches wide, there is an evident tendency in such masses for the constituents to rearrange themselves, probably under the influence of heated waters as in the classical experiments of Daubrée*. The silica thus accumulates locally, and crystallizes out in nodular forms determined by the original spherulites, while materials of much more basic character than might have arisen from primary devitrification are developed in layers and patches, and prepare the rock for future physical change. It is rash to speculate on the final condition of such a rock, were it to come under the influence of mountain-building processes. Great "eyes" of quartz, however, resolvable under polarized light into granular aggregates, against which wisps of soft micaceous matter are pressed and bent, are features not unfamiliar in highly siliceous schistose rocks; and it seems probable that this differentiation and grouping of constituents would be closely imitated by further metamorphism of the lavas of Conwy and Digoed.

The consideration of the changes undergone by our own coarsely spherulitic rocks leads one inevitably to the conclusion that the bulk, at least, of the "pyromerides"† and nodular porphyries of the continent were also originally glassy rocks. Prof. Bonney has practically expressed this view in dealing with the petrosiliceous structure in his Presidential Address for 1885‡. While it is of doubtful advantage to theorize respecting rocks with which one has no field-acquaintance, a few points of evidence may perhaps be mentioned here. Vogelsang§ states that in a dyke of "Kugelporphyr" at Ozani, Corsica, the spherulites are accumulated at the sides, an observation that may be paralleled on a minute scale in the glassy selvages even of basaltic rocks, as, for instance, in a vein near Tollymore, County Down. Delesse||, again, insists strongly on the connexion between an excessive proportion of silica and the development of "globular" or coarse spherulitic structure; and it need scarcely be pointed out that this same predominance of silica characterizes the most glassy of modern volcanic rocks. The following analysis by Delesse¶ of a spheroid from the pyromeride of Wuenheim, in the Vosges, may be compared with that of the rock

* Etudes synthétiques de géologie expérimentale, p. 159, &c.

† The name Pyroméride ("only in part fusible") is due to Haüy, and refers to the different behaviour of the constituents, quartz and "felspar." (Monteiro, *Journal des Mines*, tome xxxv. (1814), p. 359.)

‡ Proc. Geol. Soc. 1885, p. 95.

§ Neues Jahrb. für Min. &c. 1863, p. 102 (Niederrhein. Gesellsch. für Natur- und Heilkunde, Aug. 6, 1862).

|| Mémoires de la Soc. géol. de France, 2me série, tome iv. pp. 325, &c.

¶ Bull. de la Soc. géol. de France, 2me série, tome ix. p. 176.

of Digoed. The silica-percentage has again, however, been probably raised by the removal of bases in solution. The specific gravity was 2.59.

Silica	88.09	
Alumina	6.03	
Oxide of Iron	0.58	
Lime	0.28	
Magnesia	1.65	
Potash.....	} 2.53 (by difference)	
Soda		
Loss on ignition	0.84	
	<hr/>	
	100.00	

De Lapparent*, again, has described a very striking pyromeride from Bouley Bay, Jersey, the spherules, which exhibit the characteristic infillings of chaledony and quartz, being 25 centim. (10 inches) in diameter; but there seems to be little doubt, from an examination of specimens of several more modest varieties occurring in the same neighbourhood, that this rock also must be numbered among the ancient rhyolites †. Perlitic structure is, moreover, known to occur in the matrix of pyromerides, as at the Rauhfels of Wuenheim ‡ and Gargalong near Fréjus §; and M. Michel Lévy ||, while discriminating between the characters of acid rocks of different geological ages, points out, with Delesse, that there are considerable resemblances between many of the ancient "porphyries" and the rhyolites of Tertiary days. Whatever the issue in particular cases, the study of the slow processes of change to which igneous masses, in common with all other rocks, are subject, cannot fail to throw a vast amount of light on relationships hitherto obscured.

I gratefully record my indebtedness to Prof. Judd for kindly given help and much illustrative material; also to Mr. F. T. S. Houghton, F.G.S., for guidance at Conway and for several microscopic slides; and to Mr. J. F. Brooks, who worked with me in the Wrekin area, and who has checked some of the chemical results. Very many of the microscopic preparations referred to have been made in the Geological Laboratory of the Normal School of Science and Royal School of Mines, in which the work of analysis was also carried out.

* "Note sur les roches éruptives de l'île de Jersey." Bull. de la Soc. géol. de France, 3me série, tome xii. p. 287.

† Cf. T. Davies, "Old Rhyolites from Bouley Bay." Min. Mag. vol. iii. (1880), p. 118.

‡ Rosenbusch, 'Mikrosk. Physiographie' (1877), Band ii. p. 83. Delesse, Mém. de la Soc. géol. de France, 2me série, tome iv. p. 309.

§ Fouqué and Lévy, 'Min. micrographique,' plate xv. Lévy, "Roches anciennes acides." Bull. de la Soc. géol. de France, 3me série, tome iii. pp. 224, 235.

|| *Loc. cit.* p. 226.

EXPLANATION OF PLATE IX.

[Where the degree of enlargement of the objects drawn is expressed by a fraction, the numerator represents the magnifying-power of the objective with which they were viewed.]

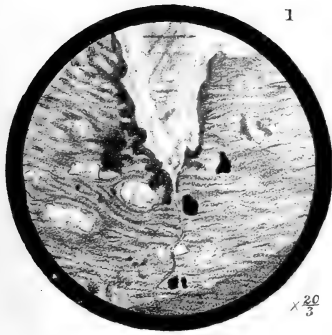
- Fig. 1. Section of end of ramification of infilled cavity in large spherulite, pitchstone of Zwickau, showing its connexion with a crack. The lines of flow are cut through by the cavity, which contains chalcedony and calcite. A portion of the glassy matrix is seen below. $\times \frac{2}{3}$.
2. Section of coarsely spherulitic rhyolite, Wrockwardine (Wrekin) area, showing difference in width of cracks as they pass from the matrix into the spherulitic matter. The matrix is seen to be perlitic. $\times \frac{2}{3}$.
 3. Large compressed spherulite, broken across, from rhyolite of Digoed, N. Wales. Extensive development of quartz and chlorite has taken place, and the residual spherulitic matter forms but a thin encircling wall. Natural size.
 4. Section of two spherulites from rhyolite of Digoed, N. Wales, showing zones of granular secondary quartz, with lines of liquid enclosures passing continuously from grain to grain. $\times 2$.
 5. Portion of the quartz of the above with lines of liquid-enclosures. $\times \frac{1}{3}$.
 6. Section of compressed spherulite in rhyolite of Conway Mountain, showing alternate concentric layers composed of a black product of alteration. $\times 2$.
 7. Section of black alteration-product in centre of spherulite, rhyolite of Conway Mountain, showing development of tufts of crystallites within it. $\times \frac{4}{9}$.

DISCUSSION.

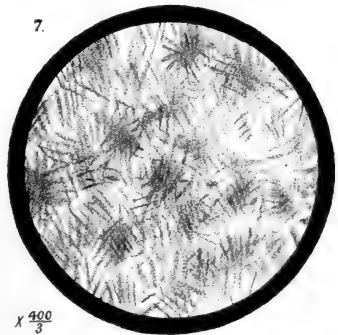
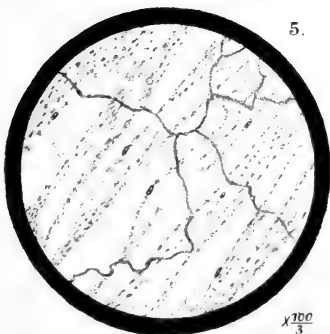
The PRESIDENT said that Mr. Cole had attacked a very puzzling problem and had given an explanation which appeared to be consistent with the whole of the phenomena.

Prof. BONNEY said that the subject was not only difficult to elucidate, but also difficult to discuss. He did not understand the formation of the supposed alteration-products from the white spherulitic rock. Again, he had noticed in one of the microscopic slides a crystal of iron-oxide close to the edge of a cavity. If the cavity was due to decomposition, why was not the crystal affected? Another difficulty was to conceive what agent could have produced the decomposition, what acid could have acted on one part of the rock, leaving other parts quite unaffected. He was rather inclined to attribute this kind of spheroidal structure to cracks forming around vesicles. The radial or true spherulitic structure was, in some cases, connected with, but subsequent in origin to, the formation of the cavity. He, however, congratulated Mr. Cole on the ingenuity of his views and on the lucid manner in which he had explained them to the Society.

Mr. RUTLEY said that he was unable to accept any view hitherto offered as to the origin of these bodies. He showed that there were several different kinds of spherulites, and gave examples. He instanced the concretions in the Magnesian Limestone of Durham as affording structure which sometimes apparently bore a certain



3.





analogy to that occurring in the large spheroidal bodies met with in the felsitic lavas of Skomer Island, and also in the forms which Mr. Cole had so well described.

Prof. MASKELYNE remarked that the solvent would more probably have been in the form of alkaline thermal infiltration than acid; but he did not understand how the black mineral was produced by simple decomposition of the white spherulitic rock. He doubted the data being sufficient to explain the action of alteration. For instance, what was the 4.37 per cent. loss by ignition? Was it all water or part of it carbonic acid? He suspected that while rocks like pitchstones differ in different districts, not merely in chemical, but in mechanical composition, the original formation of spherulitic structure was in most cases the result of contraction, owing to the minerals formed in the globules being denser and tending to shrink from the surrounding mass while solidifying.

Mr. COLE, in reply, said he had been greatly indebted to Prof. Bonney's papers. With reference to the alteration of the white spherulitic rock into the black product, the rock itself was not now in its original condition, and the additional alkalis of the product may have accumulated from the surrounding mass. Doubtless disintegration and infiltration had both taken place. He agreed that alkaline waters may have shared in the action. As to the hollowing of the spherulites, he referred to evidence put forward on the continent.

15. *The THAMES-VALLEY SURFACE-DEPOSITS of the EALING DISTRICT and their ASSOCIATED PALEOLITHIC FLOORS.* By JOHN ALLEN BROWN, Esq., F.R.G.S. (Read Jan. 27, 1886.)

[Communicated by A. Ramsay, Esq., F.G.S.]

[Abridged.]

THIS paper, which is but a brief epitome of my investigations, may be considered as a supplement to the valuable one by Col. Lane Fox "On the Palæolithic Implements in Association with *Elephas primigenius* in the Thames Valley at Acton"*, so far as it relates to much higher bench-deposits than those described by him.

Mr. Whitaker has described the highest of the three terraces into which he has divided the valley-deposits, as occupying the levels between 50 and 100 ft. above O. D.†, and extending up the shoulders of the hills which, to the north of the river, divide the inner valley from its wider extension of, generally speaking, low-lying Eocene deposits, now bounded by the chalk hills of Herts and Bucks. I shall now show that the high bench-deposits reach far above the 100-foot level; this fact is, however, one which Mr. Whitaker is evidently prepared for.

The high-valley gravels proper in the neighbourhood of Ealing flank the sides and, in some cases, reach nearly to the top of the hills which form the inner-valley ridge. They extend from East Acton (where the mid terrace runs up as a deposit which differs altogether in structure from the higher one, and which appears to be a redeposit of the older bed) to beyond Hayes, forming a continuous tract to the north, which reaches much beyond the Great Western Railway.

The highest ground of the inner-valley ridge above mentioned is at the Mount and Hanger Hill; the former, which rises to 204 ft. above O. D., is the site of the large reservoir made by the Grand Junction Water Company. During the excavation, I found that the summit of the hill was occupied by thick beds of gravel of a totally different character, and formed under other conditions than a fluvial or estuarine gravel, and that patches occur here and there in such a way as to render it probable that these gravels once extended right along the ridge and over Hanger Hill. The results of my observations are given in a paper, which I read to the Geologists' Association‡. The excavation disclosed long furrows filled with flint-gravel and fragments of foreign rock, which were also spread over the adjoining fields; the underlying stratified beds of white sand and loam (believed to be Bagshot) were always distinctly pressed out of the line of deposit where the jagged furrows occurred; it was noticeable that the stratified beds became again horizontal at a lower depth, thus showing that the formation was not due to the

* Quart. Journ. Geol. Soc. vol. xxviii. p. 449.

† Mem. Geol. Survey on sheet 7.

‡ "Probable Glacial Deposits at Ealing," Proc. Geol. Assoc., vol. viii. no. 3.

action of springs. In this paper I gave reasons which convinced me that these deposits of gravel and foreign rock-débris were due to the action of ice which had stranded and melted there, and thus been caused to deposit its burden of glacial detritus. These high-level gravelly deposits afford evidence of the last period of emergence, especially when viewed in conjunction with similar formations which are found surmounting Horsington Hill (256 ft. O. D.) to the north, and other elevations in Middlesex; they indicate, moreover, the period when the wider hollow between the chalk hills of greater height was submerged.

Castlebar Hill (167 feet high), which may be taken as an illustration of other hills, presents us with evidence of a character quite different, and which, so far as I know, has never been described before. On the western slope, near the junction between the Edgehill and St. Stephen's roads, there has been exposed a thick bed of gravel, sand, and loam, the approximate height of which is 160 feet. The section shows that the lowermost deposit is almost entirely composed of completely rolled pebbles, which are intermixed with a few frost-split black pebbles, and that above this is sand; the abraded angular flints which usually form so large a proportion of a fluvialite deposit are absent; above the sand is a finer gravel containing a larger proportion of small angular fragments, which is associated with thin cross-bedded layers of sand and blue clayey loam, strongly indicative of varying currents. The argillaceous seams generally dip to the west in conformity with the present incline of the hill. A similar gravel occurs further east, nearly on the same level, at the junction of the St. Stephen's and Castlebar roads, so that this gravel probably continues over the rise of the hill which intervenes: these deposits overlook the Thames Valley on the south and the lower ground to the north. Similar gravels occur on the north slope of the hill, and hence appear to be out of the range of what have hitherto been regarded as bench-gravels. Thus, in one section made, about 200 feet distant from the trees which mark the former entrance to the late Duke of Kent's Park, several feet of gravel with much clay and ferruginous sand was seen at about 150 ft. above O. D.; while a little lower down, near Castlebar Court, a similar formation occurs. Gravel is met with at other places along this north slope.

What has hitherto been considered true bench-gravel (*i.e.* the usual stratified beds and brick-earths) commences in this district on the flanks of the hills at 130 feet, and is bounded northwards and upwards by London Clay, or stiff brick-earth much resembling it. This clay-covered area, which extends north from near the Longfield avenue to the beach-like gravels at the summit of the hill, contains pot-holes or depressions filled with gravel, which, as it would seem, indicate the former continuity of the higher and lower gravels; similar pot-holes of gravels were noticed between the Waldeck Road and Cleveland Road, again connecting the terrace-deposits with the beach-like formation, &c., at the latter.

I have a well-formed implement which was found in gravel to the north of the Longfield Avenue (125 ft. above O. D.); it was

discovered beneath 14 feet of brick-earth and gravel. It is black, but much abraded.

On the southern shoulders of the Mount there is a deposit of loamy sand and sandy clay surmounted by trail, the agglomerated stones of which are often cemented by iron oxide into concretions; it is over 15 feet in thickness. This deposit reaches to the 130-foot contour, and is divided from the glacial deposits above by a band of London Clay.

From the foregoing evidence, I am induced to believe that these lower gravels were connected, until denudation severed them, with the more beach-like deposits on the top of Castlebar Hill, if not also with the "furrow" or Glacial gravels, &c. on "the Mount," and that all are essentially parts of but one series of deposits. The pebbly gravels at 155 to 160 feet above O. D. must be very ancient, so ancient, indeed, that they would appear to have been accumulated when the physical geography of the country was altogether different from what it is now. It would seem as if the northern tributaries could not have been then eroded; that very little, if any, of the present conformation of the Thames Valley had been fashioned; and that, so far as the present surface does coincide with that of this olden time, it was submerged beneath those waters (possibly marine or estuarine) which deposited this gravel upon ground just emerging above the waves, which covered the Eocene area to the north, and lapped the islands formed by the higher ground of Harrow, Horsington, and other hills.

Although there is no positive evidence of any undisturbed land-surface belonging to this early period upon which man may have lived, it is possible that some of the most abraded implements in my collection, the surfaces of which are almost destroyed, may have been made at that time.

The next series of beds in chronological succession present us not only with man's handiwork, but with evidence that he lived in the Thames Valley at successive levels up to the period when the brick-earth series of loams, sands, and trail covered up and preserved the works of Palæolithic man of the Drift.

The variation in the thickness of the brick-earth series on the high-terrace gravels is very remarkable; the following is one striking instance out of many:—On the line of the Avenue Road from Castle Hill Station, where the gravel reaches to the surface, and shows but small traces, if any, of brick-earth above it, northward to St. Stephen's Church, the gradually deepening deposits of the latter formation are very noticeable. Commencing at the Pymont Road, it is found to be 6 feet thick at the Albany Road; it increases to a considerable extent at the Arlington Road, and develops to a thickness of over 21 feet near the Waldeck Road, with only about 2 feet of gravel underlying it, making the whole thickness of the valley-deposits at this spot (about 126 ft. above O.D.) 23 feet; beyond this it becomes shallower and thins out to the north, and is succeeded by London Clay with the pot-holes of gravel I have described, connecting the deposits with the thick beds I have mentioned near the

summit of Castlebar Hill; vegetable remains have been found in it. This brick-earth therefore forms a bed in the gravels more than a quarter of a mile long.

The partial absence of the valley-deposits from this London-Clay area is doubtless due to denudation; and this may probably have been brought about by the same conditions which laid bare the strips of London Clay which, as Mr. Whitaker has observed, separate the high-terrace from the mid-terrace deposits.

I have found that beds of loam and gravel, apparently corresponding in age and level with the high-terrace gravel (between 90 and 130 feet), may be traced in the country to the north of the ridge which, in this district, has usually been considered to be the limit of these deposits. The evidence is briefly as follows:—A bed of mottled sandy clay was lately exposed on the north side of the avenue leading to the grounds of Twyford Abbey. It was about 5 feet in thickness, and traceable fully three quarters of a mile along the road eastward (about 117 feet above O.D.); it extended some distance up the northern slope of the hill forming part of the ridge. I have seen sections of gravel 7 or 8 feet thick at Alperton, and noticed at the base of the deposits a bed of large-stone gravel (like that which characterizes the base of the high-bench gravels), containing blocks of abraded Sarsen stone, one of which was 3 feet across and must have weighed about 7 cwt.

Beds of about 8 feet in thickness occur in brick-fields at Sudbury, while a low hill to the east of these works is largely composed of valley-deposits which are said to be of the depth of 25 feet. I saw many boulders of water-worn Sarsen stone which were taken from it, from 18 inches to more than two feet in diameter. Eastward of Acton Wells there is a considerable deposit of sand at 106 feet above O. D. At Harlesden Green (about 140 feet above O. D.) and its neighbourhood, brick-earth occurs in patches, while valuable beds of the same material likewise occur at Harrow Weald, Northolt, and Greenford; large boulders of Sarsen stone are found on or just beneath the surface of the land.

These facts appear to indicate that during the period when the lowermost beds of the high bench were being accumulated, similar gravels of less thickness were being laid down on the Eocene area to the north, and that such formations may have continued up to the time when the brick-earth series set in.

Old Land-Surfaces.—The high-terrace gravels between 60 and 125 feet contain seams of black matter (carbonate of iron or manganese). These appear to be due to the decay and consequent change of vegetable matter: on examining them I found that their position and relation to each other were more or less persistent in the neighbourhood of Ealing. I soon noticed that a very distinct stratum was almost always apparent close beneath the brick-earth deposits, and that when the floor was not indicated by a seam of black matter, it was to be traced by beds of whitened pebbles and subangular fragments. Many of these fragments are coated with a deposit which looks like clay; but as it does not break up in water, it may be a clayey humus. The stones, moreover, are often eroded in such a

peculiar way as to suggest that such erosion was effected by crenic and other acids associated with humus. The bleached surface, more particularly of the larger stones, is often on the upper side only, while the under surface has the same colour as the gravel, that is, ochreous or brown, as the case may be. Some of the stones, however, do not appear to take the staining easily and remain black, as is the case with many of the flint implements.

The presence of this coating of black matter on the stones and grains of sand, together with the humus, which hides their bleached surfaces, seemed to me to form a reasonable basis for the hypothesis that these seams represent old land-surfaces; and this hypothetical suggestion became to me almost a matter of certainty when unabraded flint implements &c. were found at levels corresponding with them.

The bleached stones, porcellanized only on the outer side, indicated that they had been exposed to the sun's light and to the atmosphere for a long period; and the whitened fragments which are often found scattered through the gravel without being associated with any particular line of stratification show that these old land-surfaces had been again and again broken up and disturbed, and with them these flint implements, which have become more or less abraded owing to their having been carried about by currents from one spot to another.

Three or four more or less distinct lines of former land-surface have been traced by me in various sections between Creffield Road, Acton, and Longfield Avenue on the rise of Castlebar Hill, Ealing. One occurs at a level of from 4 to 6 feet below the surface, a second at from 7 to 8 feet, and a third (a black seam) at from 10 to 14 feet.

Although some of the unabraded implements and flakes in my collection had been found at levels corresponding with these floors, yet the majority of those hitherto discovered were more or less abraded and rolled, so that it was not until the ground was excavated in the Creffield Road, Acton, at about 100 feet above O. D., that my views were entirely confirmed.

The gravel-pits in the Creffield Road, Acton, are situated near where that road is intersected by Mason's Green Lane, about 200 yards south of the bridge over the Great Western Railway; the surface of the ground is nearly horizontal, but with a very slight incline towards the Thames, which now flows in a curve in this direction about two miles away as the crow flies.

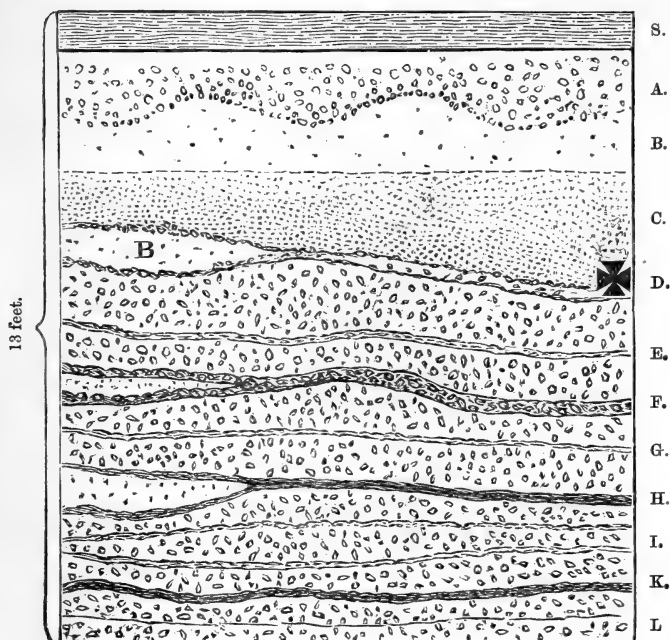
In two small pits, one about 18 feet square, and the second 30×12 , situated within 6 or 7 yards of each other, the workmen discovered, close beneath the brick-earth deposits, and about 6 feet from the surface, about 400 implements, flakes and fragments, while at the second level of 8 feet, five or six specimens were met with, and at from 10 to 11 feet three specimens rewarded me for the continued care I had given to this locality. It soon became evident that there had been a manufactory of Palæolithic implements on this uppermost floor, since they were often found together in nests, and they are all as sharp and unabraded as on the day they were made.

The underlying gravel, which at the period of its deposit formed the land-surface, and is composed of the usual subangular stones, slopes

at a greater angle than the present surface, as shown by a small circular excavation made about 120 feet to the south. In this excavation the brick-earths increased to 9 feet in thickness, and the floor was traced beneath them, in fact two worked flakes were found upon the floor, covered with the loamy sand. Coarser gravel with thin seams of sand occur as the base of the valley-deposits is reached.

Section in High-Terrace Gravel at Creffield Road, Acton.

100 feet above O. D. Pit No. 2. (Scale $\frac{1}{4}$ inch to 1 foot.)



Base not seen.

- | | |
|---|--|
| S. Surface-soil. | E. Subangular gravel with seams of sand. |
| A. Trail. | F. Bleached pebbles and humus [Flakes]. |
| B. Brown Brick-earth. | G, I, L. Coarse gravel with seams of sand. |
| C. Sandy loam. | H, K. Black seams. |
| D. Bleached pebbles &c., Floor [400 worked flints]. | |

Many of the implements associated with the blanched stones are also white, but some are more or less brown and ochreous, and a few are still black. Among the flakes, fragments, and flint nodules which have been worked, there are various tools and weapons of Palæolithic workmanship. The prevailing forms are javelin- and spear-heads, ranging in length from 3 to 6 inches; they are roughly but symmetrically chipped by secondary working to a point and

flanged at the butts, producing a rudimentary tang, and the edges are sharply bevelled.

They show, like the implements of a similar kind obtained from other parts of the district, that a regular method was in use by which these objects were made. Thus it seems evident that, after striking single-ridged flakes from the cores, so as to leave a hollow where the one-ridged flake had been taken off, care was taken to strike the second or double-ridged flakes about the centre, and just behind the previous point of impact; in this way a double-ridged flake was formed, having a thin end or butt, which could be easily inserted into the spear-shaft. I have small flakes from Hanwell, &c., worked on the same model, which, it is clear to me, were used as arrow-points. Besides these objects, there were many rounded semilunar scrapers, knives with worked edges, flints with neatly worked semicircular depressions, three or four awls or perforators made on the same pattern, and other worked flints. Some of the implements are rudely chipped like celts, and I have no doubt were used as such; while one fine specimen formed from a long flake is worked all round to a cutting-edge, both ends being carefully rounded. This is more like one of the Neolithic forms than is the case with specimens found in the Drift; indeed the whole contents of this Palæolithic workshop are, by their sharpness and preservation, more like a collection of Cissbury specimens, but partly or wholly discoloured, than those generally found in the Drift. I have specimens from different parts of Ealing and Hanwell, however, in the same condition. In a pit in the Chaucer Road, Acton (82 feet, O. D.), about $\frac{3}{4}$ of a mile distant, Col. Lane Fox found a number of flakes remarkable for the sharpness of their edges*. I cannot have any doubt as to the implements having remained where they were first made. They were probably left on some small island to which the Palæolithic people had retired for better security. The sandy loam which covered the flints (and which may still be seen adhering to many of them) shows that after they had been exposed to the atmosphere for a long time they were submerged beneath water, which was as calm and free from currents as that of a lagoon. It is evident from the trail-deposits of agglomerated stones, which were seen above the sandy clay and denser brown clay in the sections, that other conditions afterwards prevailed, by which they were accumulated. They are believed to be due to the slipping of ice and snow. The floor just beneath the brick-earth can be traced beyond the Great Western Railway towards Mason's Green. There is little doubt that it extends to the limit of the bench-deposit in that direction, and that it is ultimately lost in the loamy matter often seen above the Eocene clay.

I have no doubt, from what I have seen of these beds, and from the height to which this part of the terrace-deposits reaches, that such lagoons (still retaining a connexion with the main channel of the stream) extended over much of the low-lying country to the north, and were separated one from another by large tracts of low-lying swampy country. The varying thickness of the brick-earth

* *Loc. cit.* p. 456.

(already referred to) is shown near Freeland Road, about half a mile to the west; a section there shows the floor running nearly up to the surface and sloping to the west; it evidently represents a depression in the lower beds which has been filled with brick-earth. The banks of gravel exposed even *when* the brick-earths were being deposited (and which, in many cases, may have been broken up and disturbed by floods) afforded many secure sites upon which these ancient people lived.

With regard to the lower surfaces, it appears that, though subject to similar changes, they were never entirely destroyed. The unabraded implements and flakes, as sharp as these Creffield-Road specimens, which I have found at lower levels, say at 8, 10, and 12 feet all over the district, render it probable that they too have remained on the spots where they were left by the men who used them, but were covered, first with a stratum of sand, and afterwards with gravel.

The waste and slipping of the surface of the London-Clay hills in this district to lower levels, even under the present temperate condition of things, is so marked, that it must have been a very important factor, even after the waters had retreated from it. This action may be seen actively in progress on the slopes of Horsington Hill, which is exposed to the elements in all directions*.

I regret that I have never found any bones or shells in the upper terrace. I have, however, a small collection of both from the mid-terrace deposits near the boundary of Brentford with Ealing. The shells belong to the same species as have previously been recorded by Messrs. Trimmer, Morris, and Belt. The bones are:—

Cuboid of <i>Hippopotamus</i> , slightly rolled, determined by Mr. E. T. Newton, of the Geological Survey.	
Metatarsus of <i>Bos primigenius</i> or <i>B. bison</i>	} Unrolled, determined by Mr. W. Davies, Brit. Mus. Nat. Hist.
Bovine teeth, probably <i>B. longifrons</i> .	
Remains of <i>Cervus capreolus</i>	

A large number of other bones were found, including part of the jaw (probably) of *Rhinoceros*; but they are too fragmentary and too much rolled to be determined with certainty.

DISCUSSION.

Prof. T. M^cK. HUGHES asked the author whether it was possible that the series of flakes could have been swept into hollows or collected in any way from the surface. Their state of preservation was different from that of the implements from the gravels and loams, and suggested more recent exposure to atmospheric action.

Prof. W. BOYD-DAWKINS said that the discovery of floors of human occupation in the river-gravels of the Thames Valley was of con-

* According to Sir Andrew Ramsay and Mr. Whitaker, the escarpments of the Cretaceous deposits of the North and South Downs have mainly been formed by the same subaerial denudation. If this be so, then the same agents must have produced an enormously greater effect on the soft Eocene beds and alluvium in N.W. Middlesex.

siderable interest, as it confirmed the evidence already laid before the Society on the point by Messrs. Spurrell and Worthington Smith. In the floors discovered by Mr. Spurrell at Crayford the splinters had been knocked off the waterworn blocks of flint in course of manufacture, and very few of them were worked. In the case brought forward by the author the implements were worked. Palæolithic man lived at Crayford at a time when the Thames brought down no foreign pebbles; in the case before us he is proved to have lived on the banks of the river while materials derived from the boulder-drift were being deposited in the gravels. In the one case he was probably preglacial, and in the other certainly postglacial in the valley of the Thames.

Dr. WOODWARD pointed out that the best of the palæolithic implements were made from fresh, undried flints just derived from the chalk, and not from old pebbles. He thought that some of the implements were brought from higher grounds, and were not manufactured on the spot where found. He congratulated the author on the large collection which he had been able to bring together from the Thames Valley.

Mr. CHEADLE asserted that, from an examination of the sections, he could state that the furrows spoken of by the author showed no evidence of glacial origin, and that the foreign blocks were not found in the furrows themselves, but were strewn about on the surface of the field.

Dr. HICKS agreed with the last speaker that there was no evidence of the furrows having been caused by ice-action. He had seen some of the sections in question with other members of the Geologists' Association. He thought there was good evidence of the existence of the author's "Palæolithic Floors."

Mr. R. MOUNTFORD DEELEY stated that the furrows described by the author seemed to him to prove the existence of a late period of cold, coming after the deposition of some of the valley-deposits.

The AUTHOR said that the furrow-gravels were found over 200 feet above O. D., and rested on stratified sands and loamy beds, believed to be Bagshot, bent and compressed together under the jagged furrows. They could not have been formed by the washing-in of gravel by running springs, as Mr. Cheadle suggested, because the lowest strata or laminae are horizontal and parallel, and the squeezing together is just beneath the gravel, where the pressure was actually exerted, as shown in section. He asserted that he had found pebbles of quartz, quartzite, greensand, &c. in the furrows themselves, and they also occurred, associated with small boulders of granite, greenstone, Carboniferous Limestone, &c., on the surface of the ground. The great mass of unworn implements, flakes and fragments, 400 in number, were found within an area of about 40 feet square, the whole being covered up by brick-earth and trail. These implements are quite distinct in character from those which were much eroded, many of which might have been washed from higher levels. The thick valley-gravels contain many pebbles of quartzite and other foreign materials. He thought that the specimens were of very different ages.

16. *On the PLIOCENE BEDS of ST. EARTH.* By PERCY F. KENDALL, Esq., Berkeley Fellow of the Owens College, and ROBERT GEORGE BELL, Esq., F.G.S. *With an APPENDIX by Dr. G. J. HINDE, F.G.S.* (Read February 24, 1886.)

IN presenting this paper for the consideration of the Geological Society, we desire to state at the outset that it is intended only as a report upon reaching a stage in the investigation of this interesting deposit, and that any speculative remarks which we may venture to offer are intended rather as indicating certain directions to which inquiry may be turned with a prospect of useful result, than as well-matured conclusions to which we are prepared rigidly to adhere.

The materials at present available do not warrant us in taking a less guarded attitude, the list of fossils which we bring forward, though very large, being, we are convinced, capable of considerable increase by a more extended examination of the beds than we have hitherto been able to make.

The attention of the Society was first directed to the St. Erth deposits by a communication from the late Mr. S. V. Wood, which was read at an early meeting last session. That paper was considered by Mr. Wood to be of a tentative character, nothing very accurate being known of the physical conditions of the deposit, nor was there anything like a good knowledge of its contents, and it was his hope that the attention of competent geologists might be drawn to its occurrence, so that it might be worked out and surveyed in a better manner than, in his invalid condition, he was able to perform. Shortly afterwards Mr. Wood died, and by his desire the whole of the material and correspondence was placed in the hands of one of the authors of this communication, with the wish that the subject might be still further worked out, especially with regard to the Mollusca.

In the course of the last summer St. Erth was visited by Mr. Henry Keeping, who collected, in the interest of the Woodwardian Museum, a large series of Mollusca, with a few other remains, with one or two exceptions all invertebrates, these exceptions being two or three small vertebræ and two otoliths of fishes. Mr. Clement Reid, of H.M. Geological Survey, also visited the section, making observations and collecting a few shells (among which were three or four species which had not been found previously) from the spoil-heaps that had been left; but the sides had subsequently fallen in and he was unable to collect very extensively. Later on it was examined by one of us, having the kind permission of the Vicar of St. Erth, on whose glebe-land the deposit is exposed, and the result of these several visits has been to materially increase the list of species above that which was known at the time Mr. Wood's paper was read.

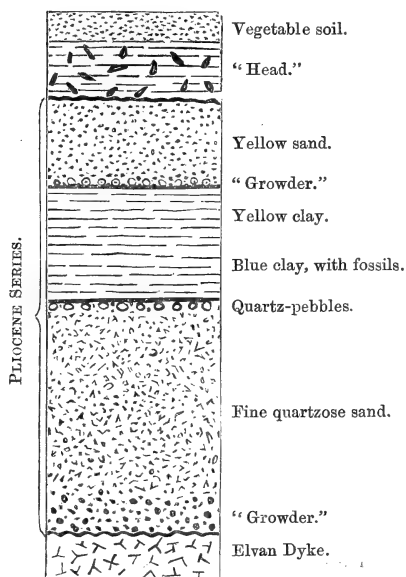
At present the number of known and described or named species amounts to seventy-two, while there are about twenty more which

do not seem to be known, either in a fossil or recent state; of these, some few were named by the late Mr. Wood in MS., and, as such, have been included in the synoptical list of Mollusca appended; but the authors have thought it better to postpone the naming and description of any other new species until further specimens have been collected.

The various deposits are to be seen in a sand and clay pit excavated upon the N.W. slope of the hill upon which stands the vicarage of St. Erth, and at an altitude of 100 feet above O. D. Other exposures will be mentioned in the sequel.

The succession of the beds is shown in the section subjoined (fig. 1).

Fig. 1.—Section at St. Erth.



The Bed 1, or "Head," is an argillaceous deposit containing many angular fragments of killas and other local rocks, and is probably of glacial origin. Mr. S. V. Wood identifies it with the "warp" of his memoir on the "Newer Pliocene Formation"; below this comes the series of beds with which we purpose dealing.

Bed 2 is composed of fine yellow sand, which is well exposed upon the N.E. face of the pit.

Bed 3, yellow clay without fossils, separated from "2" by a thin layer of very coarse ferruginous quartzose sand ("Growder").

Bed 4. Blue Clay, with many fossils.

Bed 5. Layer of scattered quartzose pebbles.

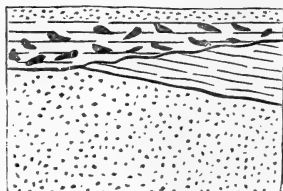
Bed 6. Fine quartzose sand, yellow above and purplish below.

Bed 7. Very coarse highly ferruginous sand ("Growder").

One observed dip gave about $3\frac{1}{2}^{\circ}$ to 4° to N.N.W.; but the true dip is probably 5° .

Mr. Wood states, on the authority of Mr. Cornish, that the clay occurs as a lenticular patch in the midst of the sand; but though the section was much obscured when our examination was made, all the appearances then presented led to the conclusion that the bedding was quite regular (see fig. 2).

Fig. 2.—Section in West Corner of Sand-pit, St. Erth.



At a slightly less elevation to the N.N.E. a thick bed of "Growder" (probably No. 7) occurs, and about three hundred yards to the west, in a deep quarry beside the road leading from the St. Erth Post-Office to Hayle, and excavated in an elvan dyke, the "Growder" is seen resting directly upon an irregular surface of the felsite, fragments of which, in a greatly decomposed state, are imbedded in the sand. The same "Growder" is to be seen along the roadside at various points nearly as far as the village of St. Erth.

A short distance along the road in the opposite direction, in the corner of a field called "Moor Meadow," a small pond was excavated, as we are informed, in the Blue Clay, but no fossils were observed. At the present time it is filled in by surface mould, but some traces of clay could be seen.

In a lane to the south of St. Erth, a roadside-cutting is said to have exposed the Blue Clay, but only obscure traces of it can now be seen.

The extent of the lines of outcrop is not traceable on account of the covering layer of "Head," which is in many places of considerable thickness, and the cuttings necessary to confirm the statements made to us could not be made, owing to the short time available and to the inclement weather; for the same reason, dips and levels could not be taken. The area embraced by these alleged exposures is about one hundred and twenty acres.

The lithology of these beds cannot be treated exhaustively in this communication, owing to the difficulty of obtaining clean and un-mixed specimens, consequent upon the falling in of the side of the pit.

The sands are of well-rounded quartzose grains, primarily derived from some Plutonic rocks. Black grains occur, which are probably hornblende.

The difference in colour of the two clays is, no doubt, attributable

to the oxidation of the upper part, though it should be noticed in this connexion that the yellow clay is almost destitute of fossils, only fragments being found. The washings yield, according to Mr. Wood, about 1 per cent. of angular rock-fragments, mostly killas, and some vein-quartz; the finer washings also show abundance of fine angular quartz grains, and some mica.

The clay-bed, No. 4, seems to be the deposit in which nearly all the shells and other remains are found; but this does not seem to be uniformly fossiliferous, as a large quantity obtained for examination by Mr. Wood was very barren, while careful washing and sifting of about thirty pounds weight from another part yielded nearly the whole of the smaller species of Mollusca recorded, and brought to light many species of *Rissoa*, *Odostomia*, and other genera, with a quantity of the fry of the larger species.

The fossils are in general very strong and in good condition, the finer striæ and ornamentation even of the Foraminifera being well preserved, probably owing to the tenacious character of the matrix. It is remarkable, however, that the larger bivalves are almost all fragmentary, the oysters alone being generally found in a tolerably perfect condition: this may probably have been owing to the presence in the St. Erth sea of a large number of predatory fishes, such as the Wolf-fish (*Anarrhichas lupus*), which breaks up the strong shells of *Nucula* and *Pectunculus* with its solid pavement of teeth.

So far as investigation has been carried out in this deposit, nearly all the palæontological evidence obtained has been confined to the Invertebrata; the only remains of a higher class consist of a few undeterminable fish-vertebræ and otoliths.

Several species of Polyzoa occur, all of which have a wide geographical range, mainly southern; the encrusting forms were attached to the interior of Gastropods, and single detached cells are found in the fine washings; but it is a remarkable fact that we have not found a single example upon an oyster, *Pecten*, or any other bivalve which usually forms their habitat. The following species have been determined:—

Melicerita Charlesworthii, <i>M.-Edw.</i>	|	Lepralia Pallasiana, <i>Moll.</i>
Salicornaria (Cellaria) sinuosa, <i>Hassall.</i>		— (Microporella) violacea, <i>Johnston.</i>

All these occur in the Coralline Crag and the Italian Pliocenes. No characteristic northern species has been found. Fragments of *Balanus* occur, and several species of swimming Crabs are represented by chelæ and fragments of the carapace. Detached plates of *Echini* and portions of the test of an irregular Echinid abound; also the spines of both groups. We have also found three or four species of Annelida and a Nullipore (*Melobesia*, sp.), and in the fine siftings spicules of calcareous sponges, upon which Dr. Hinde has appended a note. Shells bored by *Cliona* are also found.

An interesting discovery is that of an Alcyonarian.

Plates referable to the Holothurias (*Cucumaria*, sp.) are fairly common.

But perhaps the most remarkable of the fossils of this deposit

are some minute stellate spicules of calcareous composition which, with the kind assistance of Mr. Ridley, of the British Museum of Natural History, we determined to belong to an order of the Invertebrata which has never before been found in a fossil state, viz. the Tunicata; but in order to make quite sure of its affinities, we submitted specimens to the judgment of Professor W. A. Herdman, of University College, Liverpool, who confirmed our determination, and pronounces it closely allied to *Leptoclinum tenue*, a species to be mentioned in the second part of his report on the 'Challenger' Tunicates, which is now in the press.

The Foraminifera and Ostracoda are present in large numbers; of the former Mr. F. J. Millet, of Marazion, found about one hundred and twenty species and varieties; and the Ostracoda, which are in the hands of Messrs. Brady and Robertson, seem individually quite as numerous, every part of the clay from bed No. 4 yielding multitudes of examples of both these groups.

With regard to the Mollusca, which, as in nearly all other deposits, present the best means of determination respecting age, climate, and other conditions, much, in our opinion, remains to be learned; but enough is known to enable us, with some degree of certainty, to confirm the view expressed by the late Mr. Wood as to the date of the Blue Clay; we think there is little doubt of its being of Pliocene age and contemporary with the middle or lower portion of the Red Crag. Several remarkable shells, which have always been regarded as characteristic of that deposit, occur here, such as *Littorina subaperta*, *Conovulus pyramidalis*, *Nassa granulata*, and *Columbella sulcata*; the first two occur only in the Red Crag and one of the Belgian upper Crags, the last not earlier than the Coralline Crag, where it is very rare, and certainly not the same form as the single St. Erth shell, which is large, and resembles the coarser varieties of the Middle Red Crag. The large numbers of *Nassa serrata* or *reticosa* (these species are undistinguishable), *Turritella incrassata*, and *Natica millepunctata*, which similarly occur in plenty in both deposits, tend to the same conclusion as to the identity in time of the St. Erth deposits and the Red Crag. At the same time it must not be overlooked that a small number of important and prominent species occur at St. Erth which have no representatives in the Crags of Suffolk, and are entirely of a southern character, such as *Fusus corneus* or *lignarius*, *Nassa mutabilis*, *Cardium papillosum*, and *Cardita aculeata*. Three of these species have never been found in Great Britain, either fossil or recent, and, excepting in the Italian Pliocenes and French Miocenes, have never before been noticed north of the Mediterranean and Cadiz; and it will be observed, on reference to the synoptical list at the end of this paper that, with the exception of three species of small size, nearly the whole of the shells which have a living-range into the seas of Norway, also extend in a southerly direction into the Mediterranean.

It may be as well to call attention to the large size of these St. Erth examples of peculiarly Mediterranean Mollusca, such as *Nassa mutabilis*, *Turritella incrassata*, &c.; these far exceed any examples in the seas or formations of Southern Europe, and although

we cannot offer any adequate explanation of such extreme size, it is worthy of note.

The remarkable character of the fauna appears to point to certain conclusions of great moment, and, with the reservations stated at the outset, we venture to bring them forward in the hope that the criticism to which they will doubtless be subjected will, whether favourable or otherwise, give us a secure standpoint from which to view the great mass of additional evidence which will assuredly be brought to light when the deposit is submitted to a closer and more exhaustive examination.

Taken as a piece of negative evidence, the southern facies of the fauna may be inferred from the total absence of the boreal or arctic forms of predatory Mollusca.

Of such shells as *Fusus antiquus*, *F. gracilis*, *Buccinum Dalei*, and *B. undatum*, which are so common in the Red Crag, no trace has been found. *Turritelle* and other shells have been found to be bored by carnivorous Gastropods, but the abundance of the large *Nassa serrata* will account satisfactorily for this circumstance.

We think, however, that this absence indicates the prevalence of physical conditions in the British area and Western Europe generally very different from those now obtaining.

If a comparison be made between the fauna of those few Upper Tertiary beds which have been noticed in the Channel and the West of England, and is further carried onward to include the Pliocene beds of the Cotentin in France, it will be found that the Mediterranean element is a conspicuous feature, the whole having a southern character with a manifest exclusion of Red Crag and strictly boreal shells. The beds of the Cotentin have been worked by MM. Gustave Dollfus and Vasseur, and through the kindness of the former gentleman we have received a more complete list of the fossils of that region than is usually obtainable; and though they appear to us to be of an earlier date than the St. Erth clay (probably being of Coralline-Crag age), they approximate sufficiently closely to admit of their inclusion in the same statement.

Even in the most recent of the deposits mentioned, viz. that at Selsey, the *Fusi* before alluded to are entirely absent, and even in recent times they are rare at the western end of the Channel.

The Mediterranean aspect of the fauna down the western seaboard of France in Mio-Pliocene times has long been noticed; but no special significance was attached to it in consequence of the proximity of the Spanish province, which has no really distinctive fauna, but merely a blending of northern and southern forms, and during a warmer period the former element might easily have been excluded by climatal unsuitability.

We have shown, however, that the St. Erth deposit was probably accumulated during the earlier portion of the Red Crag period, when the premonitory refrigeration of the Glacial epoch had gone on so far as to permit of a great descent of *Boreal* or even Arctic Mollusca; and in the oldest Red-Crag deposit, that of Walton-on-the-Naze, 30 species occur which have an exclusively northern range in

Recent seas. Several of these may be called prevailing shells, for example *Buccinum Dalei*. The absence of such shells in a locality only 100 miles further south is to us quite inexplicable on any hypothesis which takes the physical features and distribution of land and water in Western Europe as they now are. Mr. Wood, in his paper, alluded to the difference observable between the Eastern and Western Pliocene faunas, and considered that the existence of a land-barrier which stretched across the eastern end of the English Channel would explain this, as the communication between the St. Erth Sea and that portion of the North Sea in which our Crag beds were deposited would then be round the north of Scotland, which is 9° of latitude from St. Erth.

This explanation would be satisfactory as accounting for an absence of southern species in the East Anglian area, which, however, we do not observe, while it wholly fails to account for the arrest of the south-westerly migration of shells of northern habitat.

We think that the facts at present before us point to the conclusion that, at the period of which we are writing, no channel of direct communication existed between the North Sea and the Atlantic Ocean, the Straits of Dover in the south being closed, while on the north-west the Tertiary Volcanic chain threw a barrier across from the north of Scotland to Greenland by way of the Shetland and Farøe Islands and Iceland.

The study of the present configuration of the North Atlantic seabottom is strongly confirmatory of this opinion. The 100-fathom line encloses the Orkneys and Shetlands, while a long submerged ridge with deep water upon each side extends from the Hebrides to the Farøes and, as has been so fully explained by the late Dr. Jeffreys, has had a great influence in preventing the intermingling of the marine faunas upon each side of it.

The component islets of the Farøe group are separated by deep narrow straits with very precipitous sides, which might almost be called fiords, and are clear indications of considerable subsidence.

From the Farøes to Iceland an undulating bottom exists, reaching a depth of 368 fathoms, whence a plunge takes place to 686 fathoms, and within 30 miles recovers to 350 fathoms.

Across the Denmark Straits, between Iceland and Egede's Land (Eastern Greenland), the depth nowhere reaches 500 fathoms, though both N. and S. much more profound depths are recorded.

From the south-western angle of Iceland a great submarine promontory runs down far into the Atlantic, carrying the 500 and 1000 fathom lines in a great sweep many degrees to the south, and upon this is situated the spot marked on the old charts as the "Sunken land of Buss." This region is mentioned by some Venetian navigators of the 14th century, who state that they found there a well-populated land, which they called West Friesland. In later records mention is made of the "Sunken land of Buss;" and even so late as 1777, charts indicated the existence of a dangerous shoal in the vicinity. Sir John Ross sounded over the spot in 1818, but found no bottom with 180 fathoms of line. To the S.W. of this point, in

lat. $56^{\circ}1' N.$, long. $34^{\circ}42' W.$, H.M.S. 'Valorous' found a depth of only 690 fathoms, and 100 miles to the west 1450 fathoms.

Thus it will be seen that a submarine ridge, the crest of which is nowhere 500 fathoms beneath the surface, extends from Scotland to Greenland, while deep water occurs on each side. The inequalities of the bottom we hold to be quite incompatible with the idea of the permanence of marine conditions over the area from times as remote as the Miocene period.

Apart from the rather doubtful "Land of Buss," evidence is not lacking on the coast of Greenland of considerable subsidence during the historic period; and this movement may be a continuation of the great subsidence which depressed the great N.W. barrier.

The former existence of such a barrier has been suggested by several previous observers, who based their opinions upon widely different grounds.

The late Prof. Forbes believed that it did not extend to Scotland during the Crag period, but to Norway; we think, however, that the presence of a great number of Arctic forms in the Craggs entirely negatives that supposition.

Prof. Boyd Dawkins has argued in favour of a western closure of the North Sea from the distribution of the Upper Tertiary Mammalia.

There are in our list only four shells which offer any obstacle to the acceptance of the theory which we have put forward.

One of these, *Cardium elegantulum*, Müll., = *C. strigilliferum*, Wood, is found in the Coralline Crag and the Cotentin Marnes à Nassa, and its *known* recent range is strictly northern, the southernmost extension being to Norway. It must be borne in mind that it is a very small shell, and that our knowledge of the distribution of small Mollusca, both recent and fossil, is very imperfect.

Columbella sulcata is only known from the English and Belgian Pliocenes; but so many allied species are found in the Italian Tertiaries that it is very questionable if it be not identical with one or other of the forms described by Bellardi.

Littorina subaperta is a very doubtful species, having a range of variation which carries it even beyond generic limits.

A much more important argument against our position is furnished by the occurrence of *Conovulus pyramidalis*, inasmuch as it is only found in the East Anglian and Belgian Upper Craggs, the St. Erth Pliocene, and the Wexford gravels and clays (Glacial). Regarding this shell, it should be noticed that there is a singular paucity of evidence respecting the marine members of the genus.

The southern connexions of the St. Erth Sea appear to have been much more direct with the Mediterranean than at present. The Cotentin deposits, and those on the Loire Inférieure and in the Bordeaux region, are in obvious relation to the Perpignan beds, and indicate a gulf extending from the Mediterranean across S.W. France and along the northern side, then cutting off the Finisterre district, throwing an arm across to the Cotentin, and thence running in a westerly direction to St. Erth.

The tract of land between the mouth of the Garonne and Perpignan attains a maximum elevation of 600 feet, according to Prof. Prestwich*, who quotes M. Virlet d'Aoust, to the effect that Pliocene beds occur on the Mediterranean slope at an elevation of 540 feet.

Dr. Gwyn Jeffreys remarked†:—"I, however, fully agree . . . that at some former period . . . there was an open communication between the Atlantic and the Mediterranean by which the fauna became diffused. I should be inclined to place the Atlantic point of communication at Bordeaux, and that of the Mediterranean at Narbonne, in the line of the Languedoc Canal, which extends from one coast to the other, and is very little above the present level of the sea. This communication must have been very wide, and it remained open during the Glacial epoch, which affected not only the N. of Europe, but also Naples, Sicily, and probably Rhodes." The Straits of Gibraltar appear to have been closed during the late Pliocene times.

Many recondite problems concerning the present and past distribution of life will, we think, be elucidated by the application of these hypotheses; and to one or two of these we may perhaps be permitted to refer, while others must be reserved for consideration in a future paper.

The speculations of the late Edward Forbes regarding a former great western extension of the continent should, we think, be carefully examined in connexion with the subject of which we are treating; but it would be foreign to our present purpose to do more than draw attention to them and suggest the propriety of such an inquiry.

His (Forbes's) theory was that a continuous or only slightly interrupted land-surface extended from Ireland to Spain in late Tertiary times, permitting of the free migration of Spanish plants to Ireland, where about 20 species still survive.

The western shores of this land he placed along the line of the *Sargasso Weed*.

Much additional evidence in favour of this view is to be obtained from the study of the distribution of Recent Mollusca, both marine and terrestrial, in the Azores, Canaries, and on the western shores of the Spanish Peninsula.

The position of the beds at St. Erth shows that some considerable movements have taken place subsequently to their accumulation; thus the beds occur at an altitude at least 200 feet above their original position of deposition, and dip about 5° to the N.N.W.

The movement which raised them was clearly not one of equal elevation, otherwise they would have no dip; so that it seems safe to assume that it was an undulatory or tilting movement, like in kind, though in less degree, to that now affecting the Scandinavian peninsula.

Reversing this movement to restore the beds to their original position, we should have a broad gulf at St. Erth and to some distance eastward. The fulcrum would be about 1 mile to the W.; and

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

† Shetland Report, Brit. Assoc. 1868.

TABLE (continued).

SPECIES FOUND AT ST. ERTH.	MIOCENE.			PLIOCENE.				ENGLISH CRAGS.			LIVING.					Remarks.		
	Belgium.	France.	Vienna.	Italy.	France.	Italy.	Belgium.		Cor. Crag.	Lower Red Crag.	Upper Red and Norwich Crag.	Mediterranean.	Atlantic.	England.	Scotland.		Norway.	
							Zone of I. Cor.	Zone of <i>Fusus antiquus</i> .										
<i>Ostostomia plicata</i> , Mont.	
— <i>intersincta</i> , Mont.	
— <i>insculpta</i> , Mont.	
— <i>spiralis</i> , Mont.	
— <i>clathrata</i> , Jeff.	
— <i>eximia</i> , Jeff.	
— (Chennitzia).	
— <i>costellata</i> , Grateloup	
— <i>plicatula</i> , Brocchi	
<i>Eulima polita</i> , L.	
— <i>intermedia</i> , Cantr.	
<i>Calyptiræa chinensis</i> , L.	
<i>Chiton</i> , sp.	
<i>Conovulus pyramidalis</i> , J. Sow.	
<i>Cylichna truncatula</i> , Brug.	

Dredged at Galway.

Does not live north of Cardigan Bay.

assuming the area affected to have extended 50 miles in a westerly direction, we should have the whole of the "Lyonesse" above sea-level, while if carried still further all the sea-bed between there and Ireland would be laid dry.

We trust that these views will not be looked upon as too speculative. Probably the further investigation into the St. Erth deposit which we desire to pursue may provide us with more direct evidence, both physical and palæontological, regarding the peculiar deposit which we have brought again under the notice of the Society.

APPENDIX.

On the Sponge-spicules from the Deposits of St. Erth.

By DR. G. J. HINDE, F.G.S.

The spicules occurring in the material are exclusively those of Calcisponges, and they are completely detached from each other and dispersed amongst the débris. They are all more or less imperfect, having portions of one or more of the rays broken or worn away; and their surfaces in some cases show marks of erosion, but in other instances they are as smooth as in recent spicules, and present an equally glistening aspect under the microscope. Between crossed nicols they exhibit the same chromatic effects as the spicules of recent Calcisponges. In a few instances also axial canals of very slender proportions can be detected. The spicules consist of slightly curved acerates and three-rayed forms; the rays of these latter are straight or slightly curved, either subequal, or with two rays equal and the third longer or shorter than the others (sagittate, Hæckel). There are also four-rayed spicules, the fourth, or apical ray as it is termed, being apparently shorter than the others. On account of their fragmentary condition, it is somewhat difficult to determine their original dimensions with any exactness and, consequently, to refer them to known species. The acerate spicules are portions of large forms; the longest fragment is 1.13 millim. in length by .066 millim. in thickness. In the smallest three-rayed spicules met with the rays are .12 by .02 millim.; but the rays of the majority of the three- and four-rayed forms vary from .3 to .5 millim. in length and from .016 to .083 millim. in thickness. In one or two exceptional forms the rays have a maximum length of .7 and a thickness of .1 millim.

These spicules probably all belong to different species of the group of Leucones, Hæckel. Some correspond in form and size with those of *Leuconia Johnstonii*, Carter, and others with *Leucandra caminus*, Hæckel, whilst one or two differ slightly from those of any recent species with which I am at present acquainted. The former of these two species now exists on the coasts of Ireland, Yorkshire, Devonshire, Guernsey, and Sark, and the latter on the coasts of Devon, Norway, Portugal, the West Indies, and Labrador.

The occurrence of spicules of Calcisponges so abundantly in this deposit tends to negative the opinion, expressed more especially by Mr. Carter, that the spicules of these sponges are too unstable to be preserved in the fossil state.

DISCUSSION.

The PRESIDENT said that no discovery which had been made of late years had proved so interesting as that at St. Erth. It was cause for congratulation that the work begun by Mr. S. V. Wood and Dr. Gwyn Jeffreys had been taken up by such competent investigators as the authors of the paper.

Dr. WOODWARD regretted the absence of Mr. Bell. He had come to the conclusion also that these fossils resembled Subapennine forms. The Foraminifera had been recognized by Prof. Rupert Jones as Mediterranean in their character.

Mr. USSHER noticed the similarity of beds seen in sections on the flanks of St. Agnes Beacon to those at St. Erth. When he examined these beds no fossils had been found, and he would much like to know if further search had been made. He inquired what was the position of the St.-Erth deposits, as the presence of a "head" showed the probable existence of high ground, as at St. Agnes, talus from which had protected soft beds.

Mr. MARR said Mr. Keeping had made a good collection from this locality. He further remarked that it is impossible to argue as to the occurrence in Pliocene times of a barrier over what is now the south of England by an appeal to present physical conditions, although the authors had successfully done this by fossil evidence.

Mr. COLLINS inquired why the "head" should be called a glacial deposit. He had never found scratched stones in it or any fragments of rock transported from a distance.

Dr. HINDE said that the detached spicules were those of Calci-sponges, until recently supposed to be unpreservable in the fossil state. It was difficult to determine species from them; but, so far as he could make out, they belonged to species which are now found on the coasts of the Channel Islands.

Prof. BOYD DAWKINS said he agreed with the conclusions generally. The existence of a barrier across the Atlantic in Eocene and Miocene times was, as he had pointed out in 'Early Man,' proved by the distribution of plants and animals. At the close of the Miocene age a great geographical change took place, and it was interesting to find evidence that this barrier was not broken through. A connexion with the Mediterranean across France was also very probable.

Mr. ETHERIDGE said he had seen a part of Mr. Kendall's paper and thought his arguments feasible.

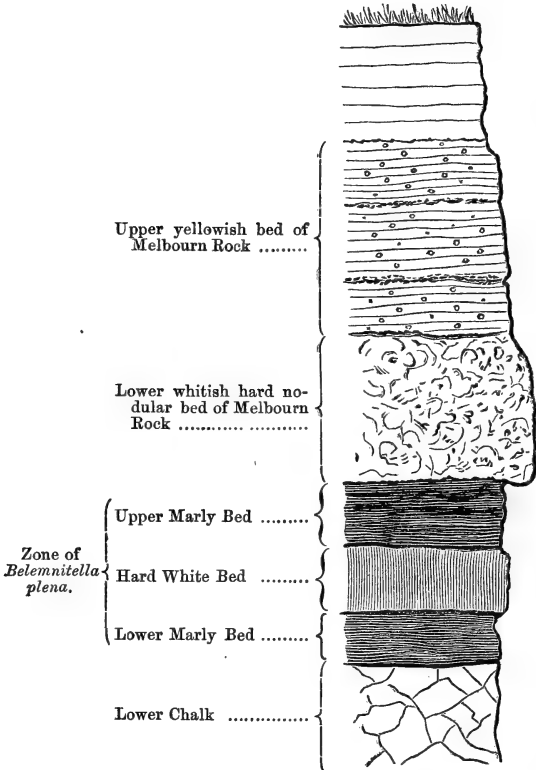
Mr. KENDALL, in reply, said he had been unable to examine the beds at St. Agnes, but hoped to do so. The configuration of the country is that behind the vicarage there rises a considerable elevation—St. Erth's Hill—whence the "head" may have been derived. It was Mr. S. V. Wood who identified this head with his "warp." He had introduced the question of the mode of upheaval of the beds merely as bearing upon the interesting speculations of E. Forbes relating to the western extension of the continent to the Azores, which was, he remarked, supported by the evidence of the land and littoral fauna. He added some evidence of Foraminifera.

17. THE MELBOURN ROCK *and the Zone of BELEMNITELLA PLANA* from CAMBRIDGE to the CHILTERN HILLS. By W. HILL, Esq., F.G.S., and A. J. JUKES-BROWNE, Esq., F.G.S. (Read February 10, 1886.)

§ 1. INTRODUCTORY.

THE Melbourn Rock was described by one of us in 1880* as a band of rocky chalk occurring in Cambridgeshire at a distance of about 80 feet above the Totternhoe Stone, and forming the base of a middle division of the chalk. Since then the outcrop of this rock has been traced south-westward through the counties of Hertford,

Fig. 1.—Diagram showing the usual outline of the face of an exposure where the Melbourn Rock and Zone of *Belemnitella plena* are seen. (Scale $\frac{2}{16}$ in. to 1 ft.)



* Geol. Mag. dec. ii. vol. vii, p. 248; and "Geology of Cambridge," Mem. Geol. Survey, p. 55.

Bedford, Buckingham, and Oxford, and has been found to be remarkably constant in its character and behaviour. It is generally found at the top of a well-marked feature or slope, and where it recedes into coombes, these are generally steep-sided; at the head of such valleys there are frequently powerful springs, which are thrown out by the marly beds at the base of the rock, so that it is of practical importance as a water-bearing stratum.

While one of us has been engaged in drawing this line of outcrop for the Geological Survey and in noting the exposures along its course, the other has carefully compared these sections, as they were discovered, with those previously described in Cambridgeshire, has collected such fossils as were to be found, and has cut and examined under the microscope numerous slices from the different beds of rock and from the chalk below and above. In the present communication, therefore, we propose to offer the results of our combined observations on this rocky band and the beds associated with it; and for permission to make use of the information gained during the official survey of the country, we have to thank the Director-General.

In the first place we have to announce that we recognize a zone of *Belemnitella plena* separate and distinct from the mass of the Melbourn Rock, and that consequently it becomes necessary to make some modification in the definition originally given of that rock.

The Melbourn Rock was described as consisting of several courses of hard, yellowish, rocky chalk, separated by layers of greyish laminated marl or shaly chalk, one of these marly bands always occurring at its base. It was observed that this basement marl sometimes contained rolled specimens of *Belemnitella plena*, as well as other fossils, but that otherwise the zone of *Belemnitella plena* appeared to be absent in Cambridgeshire, unless it was represented by the very uppermost portion of the underlying chalk. The facts, however, seemed to indicate that Dr. Barrois was right in regarding this marly band as a remanié bed, *i. e.* that the chalk of the *Bel. plena* zone had been destroyed and sifted by current-action, and that this marl was composed of its rearranged particles and contents. As there were in Cambridgeshire two principal layers of marl separated by a rocky band similar to the rock-beds above, the whole set of beds was regarded as forming one horizon and placed at the base of the Middle Chalk. This view was supported by the fact that the horizon coincided with a palæontological break, the assemblage of fossils found in the Middle Chalk above being very different from that in the Lower Chalk.

Our recent researches have, however, disclosed three important facts, which modify the view above given, though they by no means invalidate the conclusion that the rock is at the base of the Middle Chalk, and that it marks the incoming of a new fauna. The facts are:—(1) that the lower marl does, in many places, contain perfect and well-preserved specimens of *Belemnitella plena*; (2) that the uppermost bed of the chalk on which it rests also contains that fossil; (3) that the rock between the two marly layers is a variable

stratum, sometimes thinning out and sometimes passing into a peculiar marbled nodular rock. It appears therefore that the Melbourn Rock (as originally described) falls naturally into two portions—a marly belt at the base and a belt of rocky beds above; further that the marls were formed during the prevalence of *Belemnitella plena*, and not after its extinction.

We think, therefore, that these marls should be separated from the Melbourn Rock and regarded as representing the uppermost part of the zone of *Belemnitella plena*. We shall state our reasons for believing that these marls rest on a very uneven surface of the underlying chalk, and that the greater portion of the zone to which they belong is absent in this part of England. It is possible, however, that a part of the chalk hitherto referred to the *Holaster-subglobosus* zone really belongs to that of *Bel. plena*.

It follows from this recognition that the name "Melbourn Rock" must be restricted to the rocky beds which lie above the marly belt and which graduate into the zone of *Rhynchonella Cuvieri* (zone of *Inoceramus labiatus*, Barrois). These prove to be thicker than was formerly supposed, and where complete sections are found, as at Ashwell and Hitchin, they are from 8 to 10 feet thick; but the upward passage is so gradual that no hard-and-fast line can be drawn. They are simply rock-beds at the base of the lowest zone of the Middle Chalk; but from their hardness they form a conspicuous feature in all quarries and exposures (fig. 1), and were on this account noticed by Mr. Whitaker in Bucks as long ago as 1865*.

Our recent work therefore leaves the Melbourn Rock where it was formerly placed, namely at the base of the Middle Chalk, but a portion of what was formerly included in it is now cut off and relegated to the Lower Chalk.

§ 2. GENERAL DESCRIPTION (fig. 2).

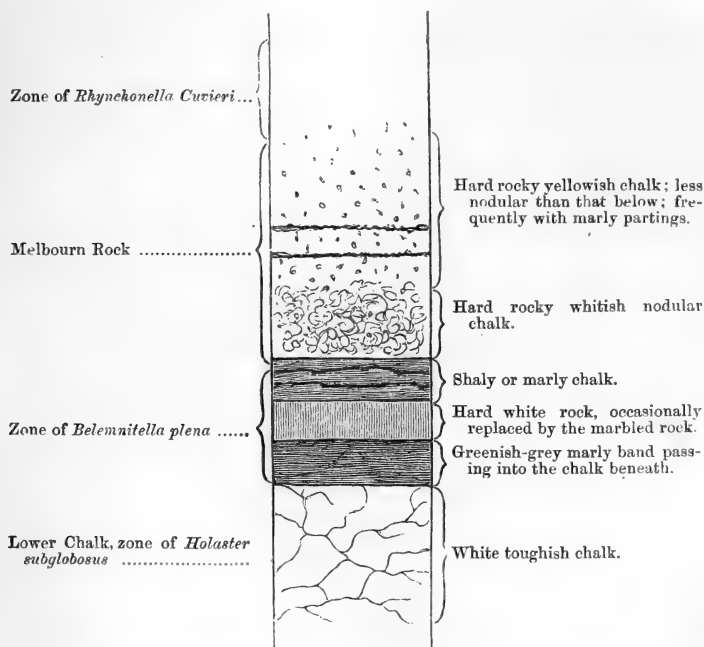
For the purposes of general description it will be convenient to take the base of the Melbourn Rock as a datum-line; because this horizon is always readily discernible in consequence of the rock resting on a band of marl, and because the beds above always exhibit the same general succession, while the beds below appear to differ in different sections and do not present a constant succession.

First, therefore, to describe the Melbourn Rock: its lowest bed is a hard nodular mass from 3 to 4 feet thick, consisting of small, hard, white nodules set in a matrix of greenish-grey chalk, the nodules varying from the size of a pea to that of a small potato. The overlying beds have generally a yellowish tinge, and the nodules in them are arranged in layers at distances of from 6 to 18 inches apart, only a few nodules being scattered through the mass; there are two or three such beds with a total thickness of from 5 to 6 feet. There are occasionally partings of marl between the rocky beds, and these also contain small hard nodules. At a height of 9 or 10 feet from the base there is sometimes a band of hard smooth rock with-

* Quart. Journ. Geol. Soc. vol. xxi. p. 398.

out nodules, but nodules occur again in higher beds and have been detected at Hitchin 25 feet from the base of the rock.

Fig. 2.—Diagram showing the usual order of succession of the Beds of the Melbourn Rock and the Zone of *Belemnitella plena*. (Scale $\frac{1}{10}$ in. to 1 ft.)



Returning now to the base of the Melbourn Rock, we find it everywhere resting on a band of shaly marl, which is from 3 to 5 feet thick and usually encloses a layer of hard white chalk. The laminated marl or shale is of a greyish-buff colour, harsh and gritty to the touch, and is generally divided into two layers or bands by the hard white chalk above mentioned. This chalk splits with a smooth even fracture, and thus differs from the rough nodular chalk of the Melbourn Rock; occasionally, however, it appears to be replaced by a very curious bed, which, when broken, presents a mottled or brecciated appearance, consisting partly of greyish and partly of white chalk. This bed we have termed the "Marbled Rock," and it closely resembles the bed which was found at a depth of 704 feet in the Richmond boring and described by Prof. Judd as "brecciated chalk"*.

The shaly marl below this marbled rock, or the white rock which

* Quart. Journ. Geol. Soc. vol. xl. p. 733.

more usually occurs, is variable in its thickness; moreover we find that it sometimes passes down into grey marly chalk, which graduates into the mass of the Lower Chalk, and sometimes it rests on a well-marked and uneven surface of tough dull white chalk, which exhibits rather different microscopical characters from that which elsewhere underlies the shaly marls. This discrepancy was for a long time a puzzle to us, but we now believe that it is due to the action of contemporaneous erosion on a much larger scale than has ever been previously suspected to occur in the chalk.

§ 3. DESCRIPTION OF SECTIONS.

Commencing at Shelford, near Cambridge, the following are the principal exposures of the zone of *Belemnitella plena* and the Melbourn Rock, as its outcrop is followed south-westward.

At Shelford, in the pit on Steeple Hill, the section seen is:—

		ft.
	Gravel	1
	Much broken rubbly chalk	3
Melbourn Rock.	{ Thin-bedded yellowish-white chalk	2
	{ Hard whitish nodular chalk with wide vertical joints	4
Zone of <i>Bel. plena</i> .	{ Grey laminated marly chalk	1
	{ Hard white chalk, rocky but with smooth fracture	1½
	{ Softish laminated chalk	1
	{ Blocky white chalk	3

The whole of this exposure is weathered, and the character of the upper portion of the Melbourn Rock not well shown.

At Maggot's Mount, in a pit west of the Obelisk at Harston, there is seen:—

		ft.
	Soil	1
	Much broken thin-bedded chalk	1½
Melbourn Rock.	{ Yellowish chalk with few nodules	3
	{ Hard whitish nodular rock	3
Zone of <i>Bel. plena</i> .	{ Greyish chalk with thin shaly bands in upper portion	2
	{ Hard white smooth chalk	2
	{ Laminated marly chalk	1

On the northern side of the pit the grey marly chalk at the base is seen to be two feet in thickness, and its passage into the white or lower chalk is not so abrupt as is usually the case.

A pit on Foston Hill gives the following section:—

		ft.
	Soil and much broken chalk	2
	Bedded white chalk, with nodules	4
Melbourn Rock.	{ Yellowish chalk, thin-bedded, with thin partings of greyish marly chalk containing nodules	4
	{ Hard white chalk breaking with rough fracture	3
Zone <i>Bel. plena</i> .	Buff-coloured marly chalk	2 shown.

The chalk here has not been worked for some time, and the upper

portion of the face of the exposure is seen weathering into nodular lumps.

At the Melbourn lime-kiln pit the section exposed is:—

		ft.
Top soil, rubble and much broken chalk.....		8
Bedded white chalk		4
Melbourn Rock.	{ Thin-bedded yellowish chalk, rather hard	4
	{ Hard rough nodular chalk	3½
Zone of <i>Bel. plena</i> .	{ Soft laminated marly bands enclosing harder greyish marly chalk	1
	{ Grey marly chalk	2
	{ Hard white rocky chalk with smooth fracture.	2
	{ Grey marly chalk	1½
	{ White chalk	2

At the northern end of this pit the hard white chalk near the base is seen passing into a nodular band, the Marbled Rock. Unfortunately a heap of rubbish hides all but a small portion of it.

There is a second pit at Melbourn, and although only a quarter of a mile distant from the preceding exposure, there is some difference in the beds.

		ft.
Soil and rubbly chalk		3
Melbourn Rock.	{ Hard whitish nodular chalk	3
	{ Yellowish laminated marl	1
Zone of <i>Bel. plena</i> .	{ Hard rocky white chalk	1½
	{ Soft grey marl	½ to 1
	{ White chalk	2

The lower marl band is variable in thickness, at some places just traceable, at others a foot thick.

The next exposure of importance to the westward is a pit by the roadside a mile N.W. of Royston, in which the section shown is:—

		ft.
Soil and chalk rubble		3
Whitish thin-bedded chalk		3
Melbourn Rock.	{ Yellowish rather nodular chalk with thin marly partings containing nodules.....	3½
	{ Hard rocky whitish chalk.....	3½
Zone of <i>Bel. plena</i> .	{ Thin bands of buff-coloured marl enclosing lenticular beds of harder and whitish marly chalk	2
	{ Hard marbled rock	1
	{ Grey marly chalk	½ to 1
	{ White chalk	6

It may be noted here that the hard smooth white chalk bed in the zone of *Belemnitella plena* is absent, and in its place is a greyish band containing many nodules of whiter material. Towards the northern end of the exposure this band becomes rather thicker, and the whiter material predominates. The band of marly chalk at the base is also more distinctly marked. This band also contains at its base many pieces of white chalk, giving it in some places a mottled appearance.

At Litlington a good exposure is seen about half a mile S.S.E. of

the village. There are two faces to the pit here, the chalk being worked so that the sides of the pit represent roughly two sides of a triangle the apex of which points N.N.E.

On the easterly side the section seen is:—

		ft.	
Melbourn Rock.	{	Soil and chalk rubble	5
		Thin-bedded rather nodular yellowish chalk with thin marly partings	6
		Hard whitish nodular rocky chalk	4½
Zone of <i>Bel. plena.</i>	{	Thin-bedded grey marly chalk with laminated marly base	2
		Hard greyish chalk with nodules (marbled rock)	1
		Greyish marly chalk	2
		passing into White hardish chalk	6
		Hard gritty chalk with a few green-coated nodules	1

As at Royston, the hard white rock is absent in the zone of *Belemnitella plena*, a nodular band being in its place. This nodule-bed thins out towards the apex of the triangle, and on the more northerly face the section is:—

		ft.	
Melbourn Rock.	{	Soil and rubble	5
		Thin-bedded yellowish chalk	6
		Hard rocky chalk	4½
Zone of <i>Bel. plena.</i>	{	Grey marly chalk, with harder central band of whitish chalk; passing into hardish white chalk, &c. (as before).....	5

Fossils, including the typical Belemnites, are abundant in the nodular bed in the zone of *Belemnitella plena*. Six feet below the marly band, which passes gradually into white chalk, there is a thin hard gritty bed with green grains and a few green-coated brown nodules. This bed is in many respects similar to the hard beds which attain a greater development and importance further to the south-westward.

A good exposure of the Melbourn Rock and the underlying zone of *Belemnitella plena* is to be seen at Ashwell, in the more easterly of two pits, in which chalk is dug for lime-burning. The section is:—

		ft.	
Melbourn Rock.	{	Soil and rubble	2
		Rather hard whitish chalk	6
		Massive bedded creamy white chalk	3½
		passing into yellower thin-bedded chalk with few nodules	2
		Hard creamy white nodular rock	3½
Zone of <i>Bel. plena.</i>	{	Grey chalk passing up into laminated marl or shale	2
		Hard white chalk	1
		Marly greenish-grey chalk	1½
		Rather rough white chalk.	

In a cutting of the Great Northern Railway at Cadwell, two miles north of Hitchin Station, the following section was seen:—

		ft.
Melbourn Rock.	Soil and rubble chalk	4
	Hard nodular whitish chalk	8
Zone of <i>Bel. plena</i> .	Grey marly chalk	2½ to 3
	Hard greyish chalk with whiter nodules (Marbled Rock)	1
	Greenish-grey marly chalk	1
	White chalk	3

A nodule-bed again occurs here in the place of the hard white chalk in the zone of *Belemnitella plena*. In it fossils are abundant, *Terebratula semiglobosa*, *Terebratula biplicata*, *Rhynchonella plicatilis*, *Ostrea vesicularis*, and *Belemnitella plena* being so thickly packed together as frequently to touch each other, but scarcely any perfect.

In the cutting of the Great Northern Railway just south of Hitchin Station a good section is seen of the chalk immediately overlying the Melbourn Rock. Only the upper portion of the Rock is now exposed.

		ft.
Zone of <i>Rh. Cuvieri</i> .	Soil and chalk rubble	5
	Whitish rather hard chalk full of fragments of <i>Inoceramus</i> (<i>Inoceramus mytiloides</i> ?)	20
	Hard whitish chalk, nodular, matrix parting the nodules veined or streaked with greenish grey	20
Melbourn Rock.	Very hard yellowish rock	4 to 6

The workmen who dig the chalk for lime-burning at the works close to the station have frequently passed through the whole series of beds which form the rock, and the underlying zone of *Belemnitella plena*. The yellow and upper portion of the Melbourn Rock is known to the men by the name of "smooth hard" chalk, while the whiter and more nodular chalk at the base is known as "curly hard."

Although the Melbourn Rock is seen at many places along its outcrop, there is no exposure in which both it and the zone of *Belemnitella plena* can be seen for nine miles.

Two miles N. of Luton, on the Leagrave Road, are some lime-works, where the following section occurs :—

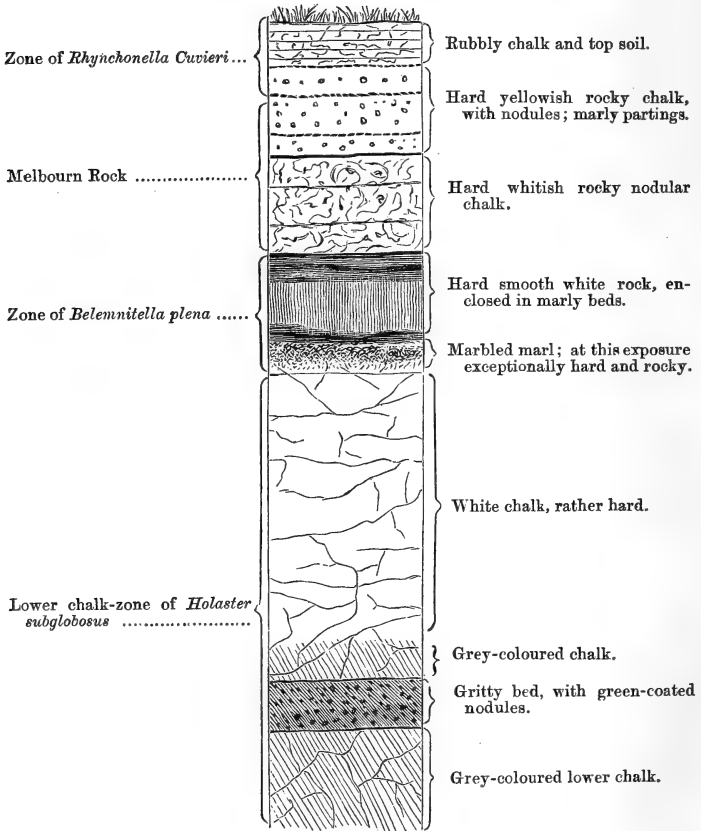
		ft.
Melbourn Rock.	Soil	1
	Rubbly thin-bedded chalk	3
	Hard nodular creamy-white chalk	7
Zone of <i>Bel. plena</i> .	Buff-coloured shaly marl	1
	Hard white chalk much broken into angular lumps	1½
	A thin layer of greyish shaly marl	—
	Dark grey marly chalk	2½
	White toughish chalk dug to	15

Two and a half miles N.E of Tring, and near Pitstone, the following section is to be seen :—

		ft.	
	Soil	1	
	Broken rubblely chalk with <i>Inoceramus mytiloides</i> and <i>Rhynchonella Cuvieri</i>	5	
Melbourn Rock.	{ Very hard yellowish chalk containing a few whitish nodules	6	
		Hard, creamy-white, rocky, nodular chalk.....	3
Zone of <i>Bel. plena</i> .	{ Buff-coloured shaly marl	1	
		Hard white chalk with smooth fracture	1
		Grey marly chalk, passing into	1
	Whiter rather tough chalk	3	

Our last section is at Chalkshire, a hamlet nearly two miles W. of Wendover. Here the following beds are seen :—

Fig. 3.—Diagram showing the order of succession of the Beds of the Melbourn Rock and the Zone of *Belemnitella plena* at Chalkshire. (Scale $\frac{1}{10}$ in. to 1 ft.)



		ft.	in.
		2	0
Soil and broken chalk			
Marly chalk with some nodules enclosing a band of hard white smooth rock		1	6
Melbourn Rock.	{ Hard yellowish rock with rough fracture	2	0
	{ Laminated marly chalk, greenish grey with small nodules	0	3
	{ Hard compact yellowish rock	1	0
	{ Laminated marly chalk	0	3
	{ Hard rock with nodules in three massive beds.	5	0
Zone of <i>Bel. plena</i> .	{ Soft grey marly chalk enclosing a lenticular band of hard white chalk	2½	to 4 0
	{ Hard grey-and-white mottled chalk	2	0
Zone of <i>Holaster subglobosus</i> .	{ passing down into smooth, hard, white chalk, greyer near the base	14	0
	{ Hard grey sandy chalk with green-coated nodules and green grains	2	6

§ 4. RELATIONS BETWEEN THE BELEMNITE-MARLS AND THE CHALK BELOW.

The difference in the nature of the chalk below the Belemnite-marls in different places led us to examine the upper part of the Lower Chalk more closely, and we found that a certain portion of it exhibited different characters from the rest, both in general external appearance and in microscopical structure. At Cherry Hinton, near Cambridge, the chalk between the Totternhoe Stone and the Belemnite-marls is about 80 feet thick; the lower part of this is ordinary grey chalk, but about 55 feet from the base of the marls the rock becomes whiter and harder, breaking with a smooth clean fracture; this firm white chalk continues for some 15 feet and then passes up into softer and more marly chalk, which, however, is still much whiter than that at the base of the zone. The harder white chalk is found by microscopical examination to contain a much larger number of the small round spherical bodies usually regarded as separate *Globigerina*-cells, than the softer chalk above, while in the grey chalk below there are very few indeed.

Similar firm white chalk is found at all exposures below the Belemnite-marls; at Ashwell and Hitchin, however, there is much less of it than near Cambridge, its thickness at these places being only from 20 to 25 feet; but the change from grey to white is so abrupt that a hand-specimen will show the two kinds of chalk.

At Totternhoe the section is somewhat anomalous; for the Totternhoe Stone here is overlain by a band of very light-coloured chalk, 8 or 10 feet thick; this is succeeded by nearly 30 feet of the usual grey-coloured chalk, which passes abruptly into whiter chalk above; of the last some 20 feet are shown, and there may be 15 or 20 feet more below the Melbourn Rock which caps the hill. Here therefore the upper white chalk must be more than 30 feet thick, and perhaps 40. From this place, however, it seems again to diminish in thickness: in the railway-cutting at Tring there appears to be only 18 feet, and at Chalkshire, near Wendover, there is not more than 10 (fig. 3); but this 10 feet consists of very firm white chalk,

which exhibits in a marked degree the characters possessed by the lowest white beds at Cherry Hinton; and it was, in fact, from finding the marls resting on this peculiar kind of chalk here that we were led to look for it elsewhere.

It appears therefore that the zone of *Holaster subglobosus* is divisible into two portions, a grey and a white, and that the thickness of the lower grey part does not vary so much as the thickness of the upper; for, if measured from the base of the Totternhoe Stone, the grey-coloured chalk varies only from 32 to 45 feet, while the upper white chalk varies from 55 to 10; and we think that this great variation is partly due to the destruction of its uppermost beds by erosion at the time when the overlying marls were being formed.

Two other points in the Chalkshire section are worthy of note; one is that the topmost foot or so of the firm white chalk exhibits a marbled appearance, and includes pipes and patches of grey chalk or marl resembling the material composing the overlying marls. It is, moreover, harder than the chalk below, and contained a specimen of *Belemnitella plena* and many minute fish-teeth; its upper surface is uneven, and the overlying marl or shale is thicker in some places than in others, as if lying in hollows. It would appear therefore that this white chalk has suffered erosion, and that when the marl was being deposited on its surface some of this marl was mixed with and piped into its topmost bed, and we think it possible that the Belemnite may have been subsequently introduced together with the grey material.

Another remarkable bed occurs below the white chalk at Chalkshire (fig. 3), and at a depth of 16 feet below the Belemnite-marls. This is a bed of hard greyish chalk about two feet thick, somewhat gritty or sandy, with scattered green grains and large nodules of hard yellowish chalk, together with many smaller nodules, green-coated, and probably containing some phosphate of lime: these nodules resemble those found at the base of the Totternhoe Stone, and are still more like those which occur in the Chalk Rock; young oysters (*O. vesicularis*) are often attached to their surface, and, when broken, their outer portion is seen to be pierced by tubular holes which are filled with greyish chalk.

The fossil contents of this bed are not many, the following only having yet been obtained, but minute fish-teeth are abundant in it:—

Ostrea vesicularis, var. Baylei.
Rhynchonella, sp.
Terebratula semiglobosa.
Inoceramus, sp.
 Fish-teeth.

This bed does not occur at Cherry Hinton or in the Grove Mill pit near Hitchin, but we have found its exact counterpart in a pit at Ivinghoe near Tring, here there is a bed about 2 feet thick of hard, grey, sandy chalk with green grains, fish-teeth, and green-coated nodules; it is locally called "rag" and rests on blocky marly grey chalk, while above it are two feet of yellowish flaggy chalk, rather

like lithographic stone, which passes up into firm whitish chalk. We should have no doubt that this was the same horizon, were it not that it is apparently, by level, only 15 or 20 feet above the outcrop of the Totternhoe Stone, whereas that at Chalkshire is about 40 feet. Moreover the distance between the Ivinghoe bed and the Melbourn Rock is 70 or 80 feet, so that either the zone of *Holaster subglobosus* is here unusually thick, or else part of it is repeated by a fault: probably the latter is the real explanation.

In the cutting of the London and North-Western Railway near Tring there is a similar bed of grey sandy rag, but it only contains a few brownish phosphate nodules, and appears to lie about midway between the Melbourn Rock and the Totternhoe Stone, which crops out at the north end of the cutting.

Some eight miles further north, in a pit halfway between Legrave and Sundon, a similar bed is exposed, which, as at Chalkshire, appears to be much nearer the base of the Melbourn Rock than the top of the Totternhoe Stone. Here the section is as follows:—

Rather hard whitish chalk, weathered	ft. 2
Hard yellowish flaggy chalk with a few nodules and fossils...	2½
Hard, grey, sandy "rag" with green grains and many large yellowish nodules	1
Tough marly grey chalk, seen for	1

As it is impossible to trace these nodule-beds through the country between these sections, we cannot say whether they are all on the same horizon, but they agree in having marly grey chalk below them and firm white chalk above them.

The only other places where nodule-beds have been observed in the chalk below the Belemnite Marls are Litlington and Swaffham Bulbeck in Cambridgeshire; but at both these localities the layer is only nine feet below the marl and does not present quite the same appearances, neither does the chalk above exhibit the same characters, being softer and passing into marly chalk, which graduates into the lower band of marl; this line of nodules seems in fact to lie in the upper and softer portion of the whiter chalk.

Taking all the facts we have been able to obtain into consideration, we think that there are two nodule-beds in this Lower Chalk, neither of which is continuous, but one sometimes occurs in the upper part, and the other in the central part of the zone of *Holaster subglobosus*. Further we think that, in some places, as at Chalkshire, a considerable portion of this zone has been removed before or during the deposition of the Belemnite Marls, the amount of chalk so removed being not less than 20 feet and perhaps more. From the levels on the six-inch ordnance map, it appears that the total thickness here from the base of the Totternhoe Stone to the Belemnite Marls is less than 60 feet, while at Cherry Hinton there is 90 or 95 feet of chalk; it must be remembered, however, that at Chalkshire the Totternhoe Stone is only 2 feet thick, while at Cherry Hinton its thickness is 12 or 15 feet. This erosion was doubtless

effected by the action of a current which was strong enough to sift and wash away the finer parts of the chalky sediment, leaving only the heavier particles to form the laminated marls; where this erosion was deepest we find the marls resting on the whiter and harder chalk; where it was least we find something like a passage from the higher grey chalk into the marl above. The nodule-bed which is sometimes found below the white part of the Lower Chalk, seems to mark a time when nodules, green grains, and fish-teeth were allowed to accumulate on the sea-bottom, and when very little of the finer kind of chalky matter was deposited over the area of its occurrence.

§ 5. MINUTE STRUCTURE OF THE BEDS.

Lower or Grey Chalk.—Between the Totternhoe Stone and the Belemnite Marls there exists a thick bed of chalk, which is part of the so-called Grey Chalk. As above mentioned the material composing the lower part of this zone is of a greyish colour and of a tough close nature; but it gradually becomes paler, and at a certain horizon, the distance of which above the base of the Totternhoe Stone may be variable, it changes to a white chalk. In thin slices seen under the microscope the grey-coloured chalk presents a constant character. It consists almost entirely of fine amorphous material in which recognizable atoms (probably of shell) may be seen in varying, but never in great, abundance; here and there specimens of Foraminifera may also be found. But about the horizon where the chalk becomes white, small spherical bodies, usually referred to as the disunited cells of *Globigerina* or other Foraminifera, appear in some abundance, and the chalk, losing its tough character, becomes more brittle, and breaks with a smooth, clean fracture. Where this chalk can be seen in its greatest development (Cherry Hinton) the *Globigerina*-cells in about 20 to 25 feet gradually disappear, and the chalk, though white, assumes something like the tough character noted at its base. At Cherry Hinton this white chalk extends from 50 to 55 feet below the Belemnite Marls; at Ashwell and Hitchin it is not more than 25 feet thick. At Chalkshire the white chalk is reduced to a thin bed about 12 feet thick, and this agrees closely with the base of the white chalk at Cherry Hinton both in structure and character. Grey-coloured chalk, also agreeing in character and structure with that at Cherry Hinton, Ashwell, and Hitchin, is seen at Chalkshire within 13 or 14 feet of the Belemnite Marls.

The Gritty Beds.—The hard nodular gritty beds which appear to occur at uncertain horizons in the Lower Chalk seem to consist almost entirely of shell-fragments with scarcely any of the finer material which constitutes the bulk of most chalk. Scattered through the mass may be seen large specimens of several species of Foraminifera, and many fragments of teeth or bone in which the minute structure is sometimes shown; grains of a clear green glauconitic mineral are also frequent. The brown nodules which occur abundantly in these beds have in structure the character of the chalk which lies immediately below them, while the tubular holes by which all are

pierced are frequently filled up with coarser material which now surrounds the nodules.

Zone of Belemnitella plena.—In thin slices under the microscope the marly chalk which always occurs at the base of this zone is seen to contain a much larger proportion of the coarser shell-fragments, such as may be seen in the Lower Chalk, and much less of the finer material, the bulk of the latter having probably been carried away by current-action.

It may occasionally be noticed that pieces of unaltered white chalk are included in this marl. These invariably exhibit the same structure as the Lower Chalk into which the marl graduates. Where these fragments are numerous (Chalkshire and Royston) the marl appears to be mottled white and grey; this we have called "Mottled Marl" to distinguish it from the "Marbled Rock," which to the eye it much resembles.

Above the marl there is usually a hard white rock. Its microscopical characters are remarkably constant. The spherical bodies (*Globigerina*-cells) before mentioned are exceedingly abundant and form a large proportion of its mass, shell-fragments being comparatively rare.

In the descriptions of sections (pp. 221–223) attention was drawn to the fact that at Royston, Litlington, and Melbourn, and in a cutting of the G.N.R. at Cadwell, near Hitchin, a hard rocky nodular bed is seen in the place of the hard white smooth rock which is a feature of this zone in many exposures.

From an examination of this "Marbled Rock" by means of smoothed hand-specimens, or thin slices seen under the microscope, it appears to consist of more or less rounded fragments of chalk, from the size of an egg to that of a pin's head, set in a greyish matrix composed largely of shell-fragments. There is no difficulty in recognizing under the microscope that the structure of these fragmentary pieces of chalk is exactly similar to that of the hard white bed. We think it is probable therefore that this bed was once continuous, but has been broken up; and portions of it in the form of lumps or nodules give evidence of its former existence. The appearance of these fragments does not favour the supposition that they have travelled far, but rather that while the chalk was only partly consolidated, it had been subject to the washing of a gentle current which carried away the finer particles and left only the *Terebratulæ* and other shells, and such portions of the chalk as were able to withstand its action. This idea receives some support from the fact that at Melbourn, as already noted, the hard white chalk is seen passing into a nodular band having precisely the same characters as those under consideration.

From the peculiar and marked characters of this "Marbled Rock" there is but little doubt that this is the same as that met with in the Richmond well-boring, and described by Prof. Judd in his paper read before this Society on "The Nature and Relations of the Jurassic Deposits which underlie London." Indeed, the characters displayed in some fragments from Richmond which Prof. Judd was kind

enough to send for examination were identical with those of specimens from these beds.

Melbourn Rock.—In smoothed hand-specimens from the lower portions of the Melbourn Rock the chalk frequently appears marbled rather than nodular, but clearly defined nodules are readily found. They are of a size from that of a pea to that of a small potato, and are set in a matrix of greenish grey material, the colour of which may be due in some measure to its decomposition; for in weathered specimens the greenish colour is more marked than in freshly dug ones. Seen in thin sections under the microscope, the matrix is found to consist of the heavier part of such material as the nodules themselves are composed of. That is to say, recognizable atoms of shell, Foraminifera, &c., such as are seen in the nodules themselves are to be found in greater abundance in the matrix which contains them.

In the upper and more yellow chalk of the Melbourn Rock the nodules are usually well defined, but are sparingly distributed through the general mass of the rock. In character they agree with the surrounding matrix, in which, as before, the heavier portions seen in the nodule are to be found in greater abundance. It may be noted that the harder the chalk is, the coarser and more abundant are the shell-fragments.

It may also be noticed that the atoms of shell &c. are sometimes arranged around the nodule in a manner which suggests either the gradual sinking of the nodule into the soft mud, or that the atoms of shell were deflected from their course by the nodule, while travelling over the sea-bed under the action of a current. That the nodules existed as nodules on the sea-bed is, we think, shown by the fact that small oysters are occasionally found adhering to them.

Above the yellowish chalk the nodules are hardly to be distinguished from the matrix which surrounds them, and they appear to become gradually lost in the zone of *Rhynchonella Cuvieri*. At Hitchin Station, however, nodules may be traced at least 25 feet above the base of the rock.

Fragments of chalk from the Richmond well-boring, from a depth of 692 to 702 feet which Prof. Judd kindly sent for comparison, agree fairly well with the succession of beds described above, the lower especially bearing a very close resemblance to the Melbourn Rock.

List of Fossils from the Zone of Belemnitella plena.

	Maggot's Mount.	Melbourn.	Royston.	Litlington.	Ashwell.	Cadwell.	Leagrave Road, Luton.	Chalkshire †.
<i>Belemnitella plena</i>	*	*	*	*	*	*	*	
<i>Inoceramus mytiloides</i>								*
<i>Inoceramus latus</i>								?
<i>Exogyra</i> , sp.						*	*	
<i>Ostrea vesicularis</i> , var. <i>Baylei</i>	*	*	*	*		*	*	*
<i>Rhynchonella Cuvieri</i>								*
— <i>plicatilis</i>		*	*	*	*	*		*
<i>Terebratula semiglobosa</i>			*	*		*		*
— <i>biplicata</i>			*	*		*		*
<i>Cidaridites hirudo</i>								?
<i>Holaster trecensis</i> or }								*
<i>Ananchytes ovatus</i> .. }								*

*List of Fossils from the Melbourn Rock. **

	Melbourn.	Royston.	Litlington.	Ashwell.	Hitchin.	Leagrave Road, Luton.
<i>Ammonites</i> , sp.					*	*
<i>Inoceramus Cuvieri</i>						?
<i>Inoceramus</i> , sp.	*	*	*		*	
<i>Spondylus striatus</i>					*	
<i>Rhynchonella Cuvieri</i>			*	*	*	
<i>Terebratulina striata</i>	*	*	*		*	*
<i>Cidaridites</i> spines	*	*	*		*	*

With the exception of the *Inoceramus*, sp., the whole of these fossils were obtained from the upper yellower part of the Melbourn Rock.

† The fossils noted as occurring at Chalkshire were obtained by Mr. Rhodes, the Geological Survey fossil-collector.

[For the Discussion on this paper see p. 247.]

18. *On the BEDS between the UPPER and LOWER CHALK of DOVER, and their comparison with the MIDDLE CHALK of CAMBRIDGESHIRE.* By WILLIAM HILL, Esq., F.G.S. (Read February 10, 1886.)

Introductory.

I PROPOSE in the following paper to give a description of certain beds lying between the Upper and Lower Chalk of Dover, and to compare them with those described as "Middle Chalk" by Messrs. Penning and Jukes-Browne in the "Geology of the Neighbourhood of Cambridge," a memoir of the Geological Survey.

The chalk of the area described in this memoir is divided into Lower, Middle, and Upper, and the authors say (on p. 20) that these divisions are founded on the combined evidence of the lithological and palæontological characters of the strata. They describe the divisions as separated by bands of chalk having marked lithological characters: that separating the Lower from the Middle Chalk is a hard nodular rock, spoken of as coinciding with a palæontological break, and is called *Melbourn Rock*: that separating the Middle from the Upper Chalk is the band of crystalline chalk, long ago brought to the notice of geologists by Mr. Whitaker, F.G.S., and known as the *Chalk Rock**.

These two bands, the authors continue, form such marked breaks that the chalk falls naturally into the divisions of Lower, Middle, and Upper; and these exactly correspond with the palæontological zones, *Cenomanian*, *Turonian*, and *Senonian*, established by Dr. Barrois and Prof. Hébert in the north of France.

Still referring to the Survey memoir, the Middle Chalk is (at p. 21) divided into four zones, viz.:—*Melbourn Rock*, as its base; zone of *Rhynchonella Cuvieri*, 60 feet; zone of *Terebratulina gracilis*, in two divisions, upper and lower, 150 feet; and on the top, the *Chalk Rock*.

Finally, with reference to the *Chalk Rock* the authors say (p. 22):—"Its fauna, which is worthy of detailed investigation, appears to contain a mixture of Middle- and Upper-Chalk forms, together with some that may be peculiar; amongst these last are several Gasteropods."

Since the memoir was written, Mr. Jukes-Browne and myself have recognized, not only in the area included in the memoir, but also through the counties of Hertfordshire, Bedfordshire, Buckinghamshire, and Oxfordshire, a zone of *Belemnitella plena*. This zone, which consists of inconstant bands of marly and rocky chalk, formerly included in the *Melbourn Rock*, forms the summit of the Lower Chalk.

General Description of the Chalk of Dover.

The lower part of the chalk between Folkestone and Dover has

* Quart. Journ. Geol. Soc. vol. xxi. p. 398, and Geol. Surv. vol. iv. p. 46.

been described by Mr. F. G. H. Price, F.G.S., in his paper "On the Beds between the Gault and Upper Chalk at Folkestone"*. He divides the chalk into nine beds. Bed 6, with its characteristic fossil, *Holaster subglobosus*, represents the division which in the geology of Cambridge is called the Lower Chalk. Bed 7 is called the zone of *Belemnitella plena*, and Mr. Price describes it as a yellowish gritty chalk, forming a marked contrast to the beds above and below. I have no doubt that this bed of yellowish chalk represents the zone of *Belemnitella plena* as recognized by Mr. Jukes-Browne and myself in Cambridgeshire, Hertfordshire, &c. As in these counties, it is marked by thin bands of laminated marl, and it contains the same fossils—*Belemnitella plena*, *Ostrea vesicularis*, and *Rhynchonella plicatilis* being the commonest forms.

Above this zone, the Middle Chalk begins. An excellent section of the lower portion of it may be seen by ascending the cliff-path at the western entrance of the tunnel of the South-Eastern Railway through Shakespeare's Cliff (fig. 1). It will be found here that the yellowish gritty chalk is overlain by exceedingly hard, rocky, nodular chalk, the first 32 feet of which constitutes the "Grit Bed" of Mr. Price. The peculiar nodular character of the chalk does not end here, but extends upward for some distance, the chalk becoming gradually softer, and the nodules arranged in layers, the last marked one being about 70 feet above the base of the "Grit Bed."

Above this the chalk is dull white, rather soft, and contains irregular indefinite lines of flints, the first flint line being about 60 feet above the nodular chalk.

The height of the cliff here is perhaps 150 feet above the base of the "Grit Bed," so that about two thirds of the Middle Chalk is shown; and although the whole of it is seen in Shakespeare's Cliff, there is no accessible place where the highest horizons can be examined. The strata dip gently to the east; and it will be found that the chalk exposed above the beach at the eastern end of the town of Dover is but little, if at all, above the horizon of that seen at the top of the cliff at the western entrance of Shakespeare's-Cliff tunnel. Here, as before, the chalk is rather soft, dull white in colour, with few flints. Several well-marked marl-bands may be seen in the lower portion of the cliff. Above the uppermost of these the chalk becomes streaked or veined with grey and harder portions, weathering into knobby lumps or projections. These lumps are of hard crystalline chalk, and frequently show the structure of sponges or ventriculites in iron-stains. From the first they show arrangement in layers, and gradually becoming closer and denser the chalk passes into a bed of rock composed of these hard lumps or nodules set in a softer matrix. Above this, similar rocky beds, at irregular distances from each other, alternating with layers of softer chalk, continue for about 25 feet; these, becoming less defined, pass gradually into softer chalk, which still contains hard crystalline lumps. There then occurs a compact yellowish rock, about 10 feet thick, which, in its turn, gradually passes into softer chalk, with layers of

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 431.

Fig. 1.—Diagram showing the Section of Chalk seen in the Cliff over the western entrance of Shakespeare's Cliff Tunnel. (Scale 30 feet to 1 inch.)

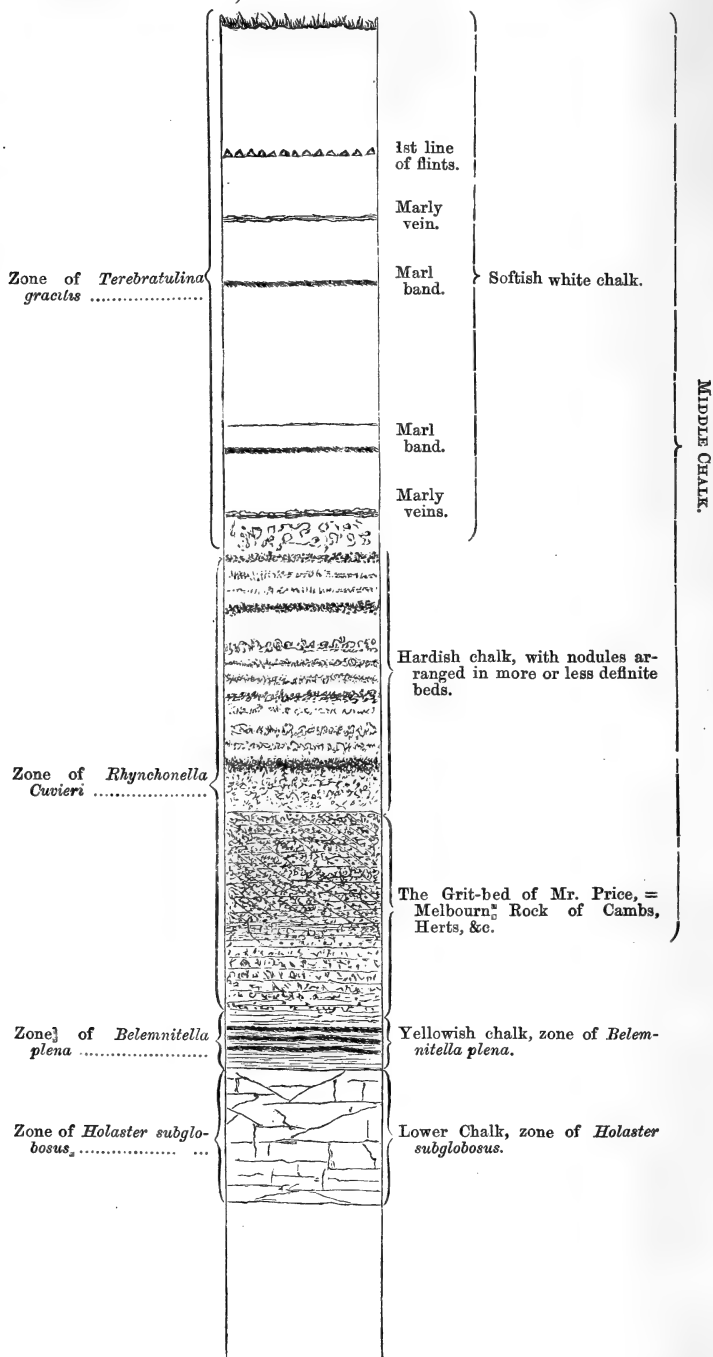
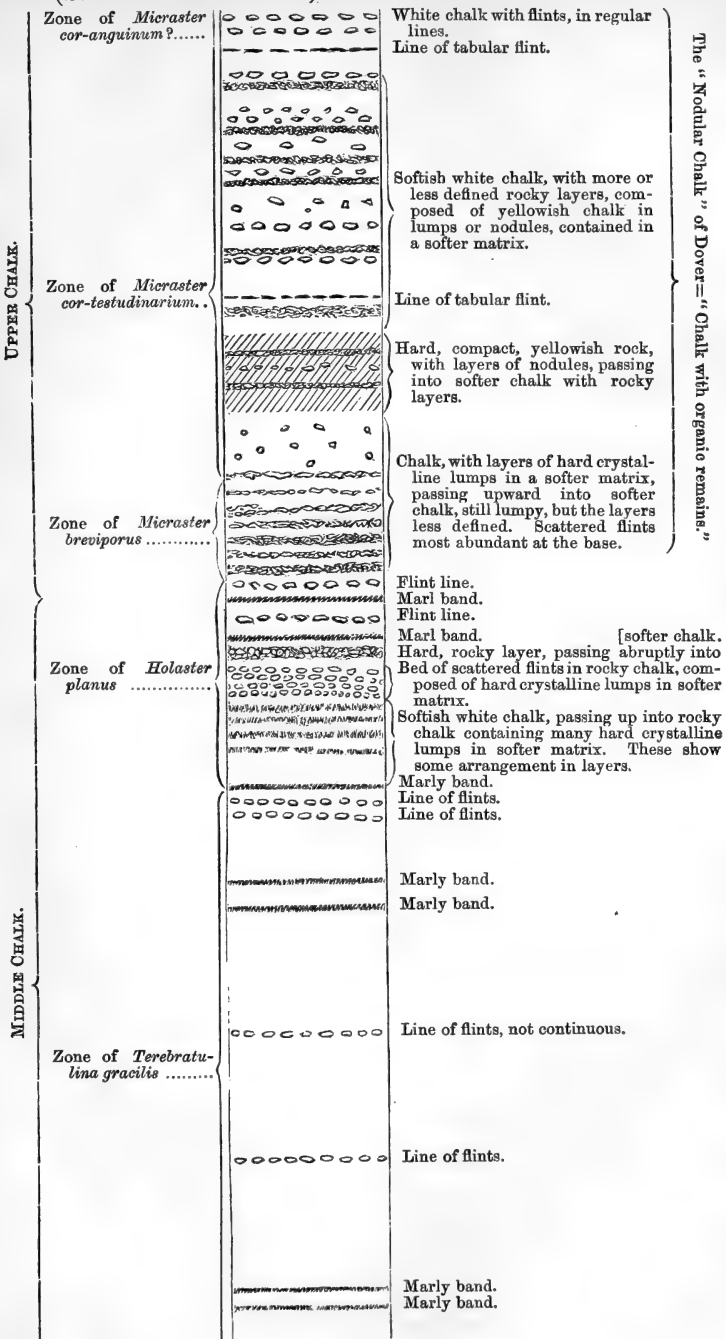


Fig. 2.—Diagram of the Section seen in the Cliffs East of Dover from the Beach to the White Chalk with regular lines of Flints. (Scale 30 feet to 1 inch.)



The measurements from which this diagram is drawn up were taken at various places between Dover and St. Margaret's Bay. There is no accessible place where the whole can be measured. My impression was that the portion of the Chalk represented by the zones *H. planus* and *M. breviporus* became thinner to the westward. The measure of this portion was taken near the South Foreland.

nodules; these are finally succeeded by the soft white chalk, with regular lines of flints. It may be noticed that the top of these rocky layers occasionally presents a definite line; the soft chalk below appears to pass up rapidly with a deepening yellowish tint into the hard rock, which ends abruptly and is overlain by the succeeding layer of softer chalk. This appearance is seen both in the lower and in the upper and yellowish rock, which, although compact, shows layers of nodules where the conditions of its weathering are favourable.

A little to the west of the South Foreland, where the base of the rocky chalk reaches the beach, there is a persistent bed of scattered flints, about 4 feet thick; this is followed by a marl-band and two well-marked lines of flints, between which is a second marl-band. These marl-bands and flint-lines are a prominent feature in the cliff-face; they are well separated at the Foreland, but approach more closely to each other to the westward.

Throughout the lower portion of the rocky chalk above the flint-lines flints are scattered irregularly, being more abundant near the base; but as the yellowish upper rock passes into softer chalk, flints become arranged in definite lines. There are two or three lines of tabular flint; these are not very persistent, but may be traced in the cliff about $2\frac{1}{2}$ miles west of St. Margaret's Bay.

The rocky beds can be examined at the stairs just west of Cornhill coastguard-station, and also by following the beach at low water between the stairs and St. Margaret's Bay.

Shakespeare's Cliff is capped by the lower portion of these hard beds; the marly band, above which the chalk becomes harder, is as nearly as possible level with the bench-mark of the Ordnance Survey, 252 $\frac{1}{2}$ feet above high-water mark. The marl-bands and flint-lines are to be seen above it, but are closer together than at the South Foreland.

The chalk of Shakespeare's Cliff, from the base of the "Grit Bed" to the lower marly band between the flint lines, has been kindly measured for me by M. Curry, Esq., Assoc. Mem. Inst. C.E., of Dover. He gives me its thickness as 236 feet. I am also indebted to Mr. Curry for the thickness of the rocky chalk. This, measured at the eastern end of the town of Dover, from the upper of the two well-marked flint lines to the highest well-marked nodular layer, proved to be 81 $\frac{1}{2}$ feet thick.

Zones of the Middle Chalk of Dover (see figs. 1 & 2).

Zone of Rhynchonella Cuvieri.—In a paper by Mr. Jukes-Browne, F.G.S., and myself, read before this Society (Quart. Journ. Geol. Soc. vol. xlii. p. 216), we say that the name *Melbourn Rock* is given to certain well-defined rocky bands which occur at the base of the zone of *Rhynchonella Cuvieri*, the structure of which is there treated at some length. Its characters are described as being gradually lost in the zone of *Rhynchonella Cuvieri*, and it contains some of the most characteristic fossils of the zone of which it forms the base.

The hard nodular chalk at the base of the Middle Chalk of Dover has all the peculiarities of the *Melbourn Rock*, but its development is

greater. The name may well be applied to the "Grit Bed" of Mr. Price, the basal 12 feet of which is certainly whiter than the hard yellowish nodular rock which forms the next 20 feet. The whole appears to be the equivalent of those beds of whitish and yellow rock which compose the *Melbourn Rock* along the line of country described in the paper referred to above.

It is true that in the Midlands this rock is only some 10 or 11 feet thick, while its equivalent at Dover is 32 feet; but as the whole of the zone of *Rhynchonella Cuvieri* consists of hard chalk, the fact that a larger part of it should consist of hard nodular rock in one place than in another is not surprising.

Cardiaster pygmaeus, by which Mr. Price distinguishes this zone, is not uncommon; but it appears to me that *Rhynchonella Cuvieri*, the fossil selected by the authors of the "Geology of the Neighbourhood of Cambridge," is to be preferred, because it is found abundantly at this horizon both here and in Cambridgeshire and Hertfordshire, where, as yet, I have not been able to find the *Cardiaster*. Moreover, the overlying 38 feet of chalk appears to me to have more in common with this nodular rock than with the softer chalk above, in which Mr. Price puts it. *Echinoconus subrotundus*, though not very common, appears in the top of the "Grit Bed" and marks the upper portion of this zone, as in Cambridgeshire, Hertfordshire, &c. The limit of the nodular chalk may be taken as about the limit of this zone, which I estimate to be 70 feet in thickness. This, while including 38 feet of the zone of *Terebratulina gracilis* of Mr. Price, agrees closely with the zone of *Inoceramus labiatus* of Barrois.

List of Fossils from the Zone of Rhynchonella Cuvieri.

	Dover.	Cambridge- shire.
Brachiolites?.....	*	
<i>Axogaster cretacea</i> , <i>Lonsd.</i>	*	
<i>Cardiaster pygmaeus</i> , <i>Forbes</i>	*	
<i>Cidaris perornata</i> (spines), <i>Forbes</i>	*	
— <i>dissimilis?</i> (spines).....	*
— (spines).....	*	
<i>Cyphosoma magnificum</i> , <i>Ag.</i>	*	
<i>Discoidea minima</i> , <i>Ag.</i>	*	
— <i>subucula</i> , <i>Leske?</i>	*	
— <i>Dixoni</i> , <i>Forbes</i>	*	
<i>Echinoconus globulus</i> , <i>Desor</i>	*	*
— <i>subrotundus</i> , <i>Mant.</i>	*	*
<i>Salenia granulosa</i> , <i>Forbes</i>	*	
<i>Serpula plexus?</i> <i>Sby.</i>	*	
— <i>antiqua</i> , <i>Sby.</i>	*
<i>Terebratula semiglobosa</i> , <i>Sby.</i>	*	*
<i>Terebratulina gracilis</i>	*	*
— <i>striata</i> , <i>Wahl.</i>	*	
<i>Rhynchonella Cuvieri</i> , <i>d'Orb.</i>	*	*
— <i>limbata</i> , <i>d'Orb.</i>	*	

	Dover.	Cambridge- shire.
<i>Rhynchonella Mantelliana</i> , <i>Sby.</i>	*
— <i>Martini</i> , <i>Mant.</i>	*
<i>Spondylus</i> , <i>sp.</i>	*	
<i>Inoceramus mytiloides</i> , <i>Mant.</i>	*	*
— <i>Brongniarti</i> , <i>Sby.</i>	*	
— <i>Cuvieri</i> , <i>Sby.</i>	*	
— <i>problematicus</i> , <i>d'Orb.</i>	*
<i>Ostrea vesicularis</i> , <i>Lam.</i>	*
<i>Hippurites</i> (<i>Mortoni</i>)†.....	*	
<i>Ptychodus decurrens</i> , <i>Ag.</i>	*
<i>Lamna subulata</i> , <i>Ag.</i>	*	
— <i>plicatella</i> , <i>Reuss</i>	*	

Zone of Terebratulina gracilis.—Above the line indicated as the top of the zone of *Rhynchonella Cuvieri*, the typical fossil *Terebratulina gracilis* occurs abundantly both in the chalk exposed at the western end of Shakespeare's-Cliff tunnel and at the east of Dover. With the exception of this, other fossils are not common, although the chalk is full of fragments. I see no reason for subdividing this zone; the fossils in the appended list were found throughout, with the exception of *Micraster cor-bovis*, which only occurred in the upper part of it.

I estimate the thickness of the zone to be 150 feet, its upper limit being about the commencement of the hard chalk.

List of Fossils of the Zone of Terebratulina gracilis.

	Dover.	Cambridge- shire.
<i>Ventriculites mammillaris</i> , <i>Smith</i>	*	*
— <i>impressus</i> , <i>Smith.</i>	*
<i>Parasmilia centralis?</i> , <i>Mant.</i>	*	*
<i>Micraster cor-bovis</i> , <i>Forbes</i>	*	*
— <i>breviporus</i> , <i>Ag.</i>	*
<i>Holaster planus</i> , <i>Mant.</i>	?	*
<i>Cyphosoma simplex</i> , <i>Forbes</i> , = <i>radia-</i> <i>tum</i> , <i>Sorig.</i>	*	*
— (species)	*	
<i>Discoidea minima</i> (<i>Ag.</i>)	*	
— <i>Dixoni</i> , <i>Forbes</i>	*
<i>Cidaris serrifera</i> (spines), <i>Forbes</i>	*	
— <i>dissimilis</i> , <i>Forbes</i>	*
— <i>sceptrifera</i> , <i>Mant.</i>	*
<i>Echinoconus subrotundus</i> , <i>Mant.</i>	*	*
<i>Hemiaster minimus</i> , <i>Ag.</i>	*	
<i>Goniaster</i> (ossicles)	*	
<i>Serpula ilium</i> , <i>Sby.</i>	*	

† This specimen was found by Mr. Griffiths of Folkestone. It occurred just above the "Grit Bed."

	Dover.	Cambridge-shire.
<i>Pollicipes striatus</i> , Darwin	*	
<i>Eschara</i> (species)	*	
<i>Terebratulina gracilis</i> , Schloth.	*	*
— <i>striata</i> , Wahl.	*	*
<i>Terebratula semiglobosa</i> , Sby.	*	*
<i>Rhynchonella Cuvieri</i> , d' Orb.	*	*
— <i>reedensis</i> , Ether.	*
— <i>limbata</i> , d' Orb.	*	
— <i>plicatilis</i> , Sby.	?
<i>Pecten Beaveri</i> , Sby.	*
<i>Lima spinosa</i> , Sby.	*	*
— <i>striata</i> , Sby.	*
— <i>Dutempliana</i> , d' Orb.	*	
— (species)	*	
<i>Ostrea vesicularis</i> , Lam.	?	*
<i>Inoceramus Brongniarti</i> , Sby.	*
— <i>mytiloides</i> , Mant.	*	*
— <i>problematicus</i> , d' Orb.	*
<i>Corax heterodon</i> , Reuss	*	
<i>Macropoma</i>	*	

Zone of Holaster planus.—The thickness of this zone I give as 22 feet. In it the chalk passes into the layers of hard rock already described. Its superior limit is drawn above the uppermost of the two well-marked flint-lines. Many specimens of sponges and *Ventriculites* can be seen at this horizon, their form and structure showing as iron-stains; but other fossils are not numerous. *Holaster planus* is certainly the distinguishing form; it was fairly abundant in the upper 10 feet of the zone, though rare in the lower portion of it. Many of my specimens were crushed or broken. The presence of this Echinoderm, unaccompanied by any other fossil of like character or in the same abundance, marks the zone clearly from the over- or underlying one.

List of Fossils from the Zone of Holaster planus.

Spongia, sp.
Cephalites, sp.
Guettardia stellata, Nisch.
Plocoseyphia convoluta, T. Smith.
Ventriculites.
Micraster cor-bovis, Forbes.
Holaster planus, Mant.
Cyphosoma simplex, Forbes, =
radiatum, Sorig.
Vermilia ampullacea, Sby.
Terebratula semiglobosa, Sby.

Terebratula carnea, Sby.
Rhynchonella reedensis, Ether.
— *plicatilis*, Sby.
Lima spinosa.
Pecten Beaveri?
Pleurotomaria perspectiva, Mant.
Scaphites, sp.
Ammonites, sp.
Ptychodus mammillaris, Ag.
Polyptychodon.

Chalk with many Micrasters.—Almost immediately above the flint line which I take as the upper limit of the zone of *Holaster planus*, the chalk, from being comparatively unfossiliferous, becomes crowded with organic remains. This division (see fig. 2), which may be said to include all the “Nodular Chalk of Dover”—the † “Chalk with [many ‡] organic remains” of W. Phillips—is distinguished by the abundance of *Micrasters*. Its thickness at the eastern end of the town of Dover is, as before stated, 81½ feet.

Zone of Micraster breviporus.—The basal portion of this division is marked by the abundance of *Micraster breviporus*. *Holaster planus* occurs rarely. Although this zone might be taken as an extension of the zone of *H. planus* §, from the occurrence of this fossil, yet, from the lithological character of the chalk, from the presence of many *Micrasters*, and also because the fossils of the appended list were to be found as generally in the zone above as in this one, it appears to me to belong to the overlying rather than to the underlying chalk. It is difficult to give the upper limit of this zone; but the abundance of *Micraster breviporus* seemed to warrant the separation of the lower 15 feet of this division. Among the many forms which are common at this horizon, are several species of Gasteropods; these may be found up to the band of hard yellow rock in the overlying zone, beyond which they do not occur or are rare.

Zone of Micraster cor-testudinarium.—Throughout the remainder of this division *Micraster cor-testudinarium* is common; other fossils are abundant in the lower part of this zone, but as the hard yellow rock passes into the soft white chalk with regular lines of flints, they gradually become less plentiful and the chalk again comparatively unfossiliferous. I do not fix the upper limit of this zone, but *M. cor-testudinarium* was to be found commonly where the upper part of this rocky nodular chalk descends to the beach at St. Margaret's Bay.

List of Fossils from the Chalk with many Micrasters (=the Nodular Chalk of Dover).—Zones of *Micraster breviporus* and *Micraster cor-testudinarium*. (The second column indicates those recorded from the Chalk-rock of Cambridgeshire.)

	Dover.	Chalk-rock of Cam- bridgeshire.
Ventriculites impressus, <i>T. Smith</i>	*	*
— mammillaris, <i>T. Smith</i>	*	*
— radiatus, <i>Mant.</i>	*
— (species)	*	
Sponge (species)	*	
Coscinopora infundibuliformis, <i>Goldf.</i>	*	

† Phillips, Trans. Geol. Soc. ser. 1, vol. v, p. 24.

‡ Whitaker, Mem. London Basin, p. 32.

§ Barrois, Ann. Soc. Géol. du Nord, vol. v, p. 400; Barrois, Bull. Soc. Géol. Fr. series 3, t. 2, p. 416.

	Dover.	Chalk-rock of Cam- bridgeshire.
Trematolites (Cephalites) perforatus, <i>T. Smith</i>	*	
Camerospongia (Cephalites) campanu- latus, <i>T. Smith</i>	*	
Plocoscyphia convolutus, <i>T. Smith</i> , = (Brachiolites)	*	
Cephalites catenifer, <i>T. Smith</i>	*	
Guettardia stellata, <i>Nisch</i>	*	*
Parasmilia centralis?, <i>Mant.</i>	*	*
Caryophyllia	*	
Micraster cor-testudinarium, <i>Goldf.</i> ...	*	*
— cor-bovis, <i>Forbes</i>	*	*
— cor-anguinum, <i>Leske</i> , var.	*
— breviporus, <i>Ag.</i>	*	*
Holaster planus, <i>Mant.</i>	*	*
—, sp. nov.	*	
Echinocorys vulgaris = Ananchytes ovatus, <i>Leske</i>	*	*
Cidaris clavigera (spines), <i>König</i>	*	
— sceptrifera, <i>Mant.</i>	*	
— serrifera (spines), <i>Forbes</i>	*	
— (spine)	*
Serpula illium, <i>Sby.</i>	*	
— plexus, <i>Sby.</i>	*	
— (species)	*	
Vermilia ampullacea, <i>Sby.</i>	*	
Enoploclytia Leachii, <i>Mant.</i>	*	
Desmopora semicylindrica, <i>Röm.</i>	*	
Pustulopora pustulosa, <i>Goldf.</i>	*	
Flustra inelegans?, <i>Lonsd.</i>	*	
Vincularia leda, <i>d' Orb.</i>	*	
Terebratulina gracilis, <i>Schloth.</i>	*	
— striata, <i>Wahl.</i>	*	
Terebratula semiglobosa, <i>Sby.</i>	*	*
— carnea, <i>Sby.</i>	*	*
Rhynchonella plicatilis, <i>Sby.</i>	*	*
— reedensis, <i>Ether.</i>	*	*
— limbata, <i>Schloth.</i>	*	*
— Cuvieri, <i>d' Orb.</i>	*	
Pecten nitidus, <i>Mant.</i>	*	
— ? (much like <i>asper</i>)	*	
— quinquecostatus, <i>Sby</i>	*	
Lima spinosa, <i>Sby.</i>	*	*
— Hoperi, <i>Mant.</i>	*
Ostrea semiplana, <i>Mant.</i>	*	
— vesicularis, <i>Lam.</i>	*	
— (species)	*
Inoceramus Brongniarti?, <i>Sby.</i>	?
— (species)	*	
— (species)	*	

	Dover.	Chalk-rock of Cam- bridgeshire.
Pleurotomaria depressa, <i>Mant.</i>	*	
— perspectiva, <i>Mant.</i>	*	*
— sp. (a deep form, ornamented) ...	*	
Turbo gemmatus, <i>Sby.</i>	*	*
— (species)	*	
Cerithium (species)	*	
Trochus Marcaisi? (<i>d'Orb.</i> pl. 186 bis.)	*	
Aporrhais (Rostellaria) stenoptera (<i>Goldf.</i>).....	*	
Solarium, sp.....	*
Ammonites Mantelli?, <i>Sby.</i>	*	
— obtectus, <i>Sharpe</i>	*	
— peramplus, <i>Mant.</i>	*	*
Scaphites æqualis?, <i>Sby.</i>	*	*
Nautilus Fleuriausianus, <i>d'Orb.</i>	*	
Ptychodus?	*	
Otodus?.....	*	

*Structure of the Hard Beds which mark the Upper and Lower Limits
of the Middle Chalk.*

Although the structure of small thin slices of chalk as seen under the microscope cannot perhaps be trusted as a means of testing its horizon, yet the similarity in the structure of the chalk in the hard beds which define and mark the limits of the Middle Chalk both in Hertfordshire and Cambridgeshire, and also at Dover, can hardly be passed without remark.

The white chalk at the base of the zone of *Belemnitella plena* is fairly constant in its microscopical characters between Cambridge and Tring, and at Dover these characters are in no way changed. The small round bodies referred to as the single cells of *Globigerina* become as suddenly abundant in the upper part of the yellowish chalk in the zone of *Belemnitella plena* at Dover as they do in the upper part of that zone in Cambridgeshire and Hertfordshire.

The Grit bed (bed 8 of Mr. Price), which forms the base of the Middle Chalk of Dover, exhibits the same nodular peculiarities as may be seen in the *Melbourn Rock*, which occupies the same horizon in Cambridgeshire and Hertfordshire.

The microscopical structure of the rocky beds which mark the upper limit of the Middle Chalk is peculiar. The usual amorphous matrix is crowded with shelly fragments, many of which exhibit a structure similar to that of the test or spines of Echinoderms; these with the sponge-spicules, Foraminifera, prisms of *Inoceramus*-shells, green grains, &c., give the chalk a marked character. At the summit of the zone of *Terebratulina gracilis* the chalk appears to be composed of *Globigerina*-cells, a few shell-fragments, and a rather large proportion of the amorphous matrix; from this there seems to be a gradual passage, and it is not till the upper

part of the zone of *H. planus*, or the horizon of the *Micrasters* and Gasteropods, is reached that this peculiar structure is fully attained. This passage may be traced in Hertfordshire and at Dover, fragments of the hard rock in which *Micrasters* and Gasteropods occur being very similar in both localities. There is one remarkable difference, however: green grains which are abundant in all Chalk Rock between Cambridge and the Thames are very rare at Dover; and the green-coated nodules which form one of the features in many exposures of the beds known as Chalk Rock in the Midlands do not occur at Dover at all. It may be noted, however, that brownish phosphatic (?) nodules are not uncommon. From such fragments as I have examined of the upper portion of the rocky beds, it appears that the peculiar structure already described passes gradually away in the hard yellowish rock, and is lost at a higher horizon.

Summary and Conclusions.

It will be seen from the foregoing remarks that there exist in the Chalk of Dover two well-marked bands having peculiar lithological characters, enclosing about 150 feet of softer chalk which contains but few flints. Both these bands appear to attain a greater development at Dover than in Cambridgeshire. The lower has all the characters of the *Melbourn Rock*, and, as in Cambridgeshire, it overlies a thin bed of marly chalk containing *Belemnitella plena*. Its development is, however, much greater, its peculiar character extending almost through the zone marked by *Rhynchonella Cuvieri*, from which zone it can hardly be separated as in Cambridgeshire. This fossil, accompanied by *Echinoconus subrotundus*, is characteristic of the basal 60 or 70 feet of the Middle Chalk in both localities. Above the nodular chalk the zone of *Terebratulina gracilis* is equally well marked in all respects. But at the summit of this zone there occurs at Dover a bed in which *Holaster planus* occurs almost alone, other fossils, except sponges and Ventriculites, being scarce; in it the chalk passes from a softish material to beds of rocky chalk composed of crystalline lumps contained in a softer matrix.

This zone of *Holaster planus* is not definitely recognized in the Survey Memoir on Cambridge; but referring to the zone of *Terebratulina gracilis*, the authors say (on page 63):—"The question, too, of further division of the Middle Chalk is one that cannot be solved in Cambridgeshire, though there would certainly appear to be palæontological evidence for separating off the upper 50 feet of this zone and constituting them into another division."

Mr. Jukes-Browne, however, in his paper* on "The Subdivisions of the Chalk," recognizes a zone of *Holaster planus* underlying the "*Chalk Rock*," and regards this rock as the topmost bed of the zone.

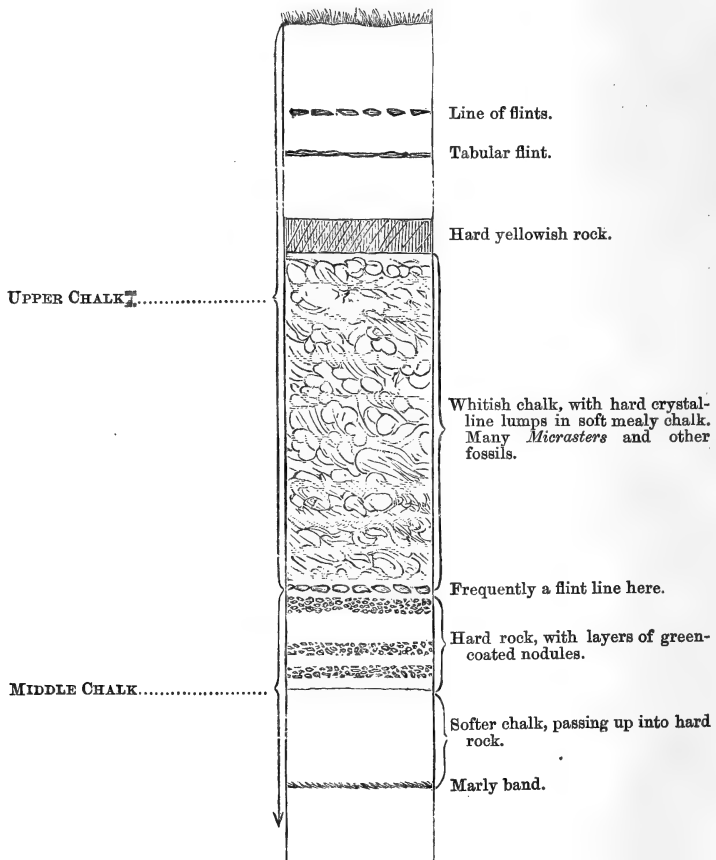
The upper limit of the Middle Chalk of Cambridgeshire is described in the Memoir as a thin band of crystalline rock containing certain fossils which may be peculiar to it; but at Dover there is a succession of bands of hard crystalline chalk to which the term "rock" may be

* Geol. Mag. dec. ii. vol. vii. p. 253.

applied; and in defining the limits of the Middle Chalk of Dover it appears necessary to consider the palæontological position of that hard bed to which the name "*Chalk Rock*" has been given by Mr. Whitaker. It is described by him* as "a hard cream-coloured chalk with layers of irregular-shaped nodules, darker, generally green-coated and slightly phosphatic; where best developed it is markedly jointed, breaks with an even fracture, and rings with the hammer."

This *Chalk Rock* as seen in the neighbourhood of Pangbourn (Hart's Lock) and Henley is a compact band of hard rock in which occur layers of green-coated brownish nodules. Where the section

Fig. 3.—Diagram showing the Rocky Beds above the "*Chalk Rock*," from Sections seen at Chinnor, Aston, and Henley. (Scale 10 feet to 1 inch.)



shows the chalk beneath, a marl band usually marks the commencement of a somewhat rapid passage from the softer chalk to the hard rock (fig. 3). The chalk below the rock appeared unfossiliferous, but Gasteropods, a few *Micrasters*, and other fossils may be found on the top of the rock. Everywhere overlying it there is white chalk containing hard crystalline lumps, and at Henley I noticed these showing some arrangement in layers. This kind of chalk may be traced for from 15 to 20 feet; it is fossiliferous and contains flints scattered and also arranged in rather indefinite lines.

At Aston and Chinnor are two good sections in which the *Chalk Rock* is exposed. Overlying it is the fossiliferous chalk with hard lumps. *Micrasters* are abundant; *Micraster cor-testudinarium* is associated with *M. breviporus*, *Echinocorys vulgaris*, *Ammonites peramplus*, Gasteropods, &c. About 20 feet above the Chalk Rock with the green-coated nodules like that seen at Henley is a second hard yellowish band, which is not nodular and very much like the hard upper yellowish rock of Dover. Flints in regular lines and one layer of tabular flint can be seen in the white chalk above the yellow rock (fig. 3).

But the "Chalk Rock" is not always compact as at Henley. Mr. Whitaker describes that seen south of Wycombe-Marsh Station (?) as "irregular in structure, not hard throughout, beds of cream-coloured rock with nodules alternating in fact with beds of chalk." Again at Jenkin's Hill "There are two bands of rock 12 feet apart; chalk without flints occurs below, chalk with flints above." And at Valenciennes Farm he records a section showing 3 layers of more or less defined Chalk Rock in about 10 feet, and above this there is "nodular yellow-stained chalk," tabular flint occurring beneath this.

At Prince's Risboro the Chalk Rock is shown in beds each with a definite line at top, the chalk passing up rapidly with deepening yellowish tint to hard rock, as at Dover, which ends abruptly, softer chalk overlying it. In Hertfordshire similar sections occur; but here the character of the rock is slightly altered, the green-coated nodules are not so evident, and it is frequently broken up into lumps with softer "mealy" chalk between them. In the Cambridge Memoir the rock is described at an exposure near Abington Park as "an irregular layer of rubbly, crystalline, yellowish chalk in lumps enclosed in a marly matrix," &c.; and N.W. of Westley as "hard chalk with several yellowish layers near the base, containing lumps of hard crystalline chalk," &c. The green-coated nodules are not noticed here at all.

Taking all the evidence into consideration, and including Dover, I come to the following conclusions, viz. :—(1) That there exists in the Chalk at a certain horizon above the base of the *Melbourn Rock* (not less than 220 feet in the localities mentioned herein) rocky bands, probably not all persistent, to which the name "Chalk Rock" may be applied; (2) That the rock seen at Henley, the characters of which are persistent over a large area, is one of these bands; (3) That these bands do not necessarily mark a palæontological horizon.

It follows that the top of the Middle Chalk must not be looked for in a thin band with peculiar lithological characters, but at a certain palæontological horizon; this horizon seems to me to be the zone of *Holaster planus*. Inland this zone is somewhat difficult to identify from the paucity of its fossils, but the base of the overlying zone is well marked throughout all the district under consideration, and at Dover by the advent of the *Micrasters* and by the incoming of an abundance of fossils having characters more closely allied to the Upper than to the Lower Chalk.

It appears to me that in the neighbourhood of Henley the Henley Rock may be taken as the summit of the zone of *Holaster planus* and also of the Middle Chalk, although, from the presence of Gasteropods &c. in its upper part, it may be the equivalent of chalk at a higher horizon elsewhere. The white lumpy fossiliferous chalk above the Chalk Rock seen at Henley appears to me to be the equivalent of the "chalk with many *Micrasters*," = zones of *M. breviporus* and *M. cor-testudinarium* of Dover, which division I should propose to take as the base of the true Upper Chalk—chalk with many flints—in both localities.

With regard to the *Chalk Rock* of Cambridgeshire, although it may form a convenient line to mark the limit of the Middle Chalk, either from want of continuous sections or the thinness of the rocky band, there has, it appears to me, been included under this head chalk which is really a portion of two zones, viz. that of *Holaster planus* and the "*Chalk with Micrasters*." Whether the rock has been reduced by erosion to the thin bed now found there, or whether there is a natural thinning-out of it, I am not prepared to say; but I would draw attention to the fact that the definite line which marks the top of the rocky layers, and is considered by the authors of the Memoir to be possibly evidence of this erosion, is a feature generally seen in the lower as well as in the higher of these rocky beds.

I take the Middle Chalk of Dover to be that included between the base of the "Grit Bed" and the top of the zone of *Holaster planus*. Its thickness and that of the various zones is given below:—

Chalk with many <i>Micrasters</i> .	{ Zone of <i>Micraster cor-testudinarium</i> ? " " <i>breviporus</i>	ft. 66½ } 15 }	ft. 81½
Middle Chalk.	{ " <i>Holaster planus</i> " <i>Terebratulina gracilis</i> " <i>Rhynchonella Cuvieri</i>	22 } 150 } 70 }	242
Lower Chalk.....	Zone of <i>Belemnitella plena</i>	6	

The flint line at the upper limit of the zone of *Holaster planus* is about 6 feet higher than the marl band which formed Mr. Curry's mark when measuring Shakespeare's Cliff.

The total thickness of the Middle Chalk at Dover is slightly in excess of the estimated thickness of it in Cambridgeshire.

Thus the zones of the Chalk as set forth in the 'Geology of Cambridge' are clearly shown in the cliffs of Dover, and the main divi-

sions receive further confirmation by the study of the chalk of our Kentish cliffs.

In conclusion, I must thank the Director of the Geological Survey for his kindness in allowing Messrs. Sharman and Newton to examine and name my fossils, and these gentlemen also for their trouble in working up my somewhat large and rough collection. I must also thank most heartily Mr. Jukes-Browne, F.G.S., for much valuable advice and assistance.

DISCUSSION.

Prof. SEELEY called attention to the importance of the proofs of erosion in the midst of the Chalk series which had been brought forward by the authors. He had himself pointed out the existence of current-bedding in a section at Cherry Hinton, and had since observed it in many other sections. He agreed with the late Dr. Gwyn Jeffreys that the lower part of the Chalk at least was deposited in moderately shallow water. There were also proofs that the Upper Greensand and Gault, older rocks, were, in some places, denuded during the deposition of the Lower Chalk. He asked for information as to whether the condition described as "brecciated" was not really "concretionary," like that seen in the Chalk Rock. He had no faith in the classification of the zones of the Chalk by means of its fossils, as hitherto elaborated; the range of the species was much longer in time than was here supposed, and their use in classification was made to depend on the accidental local abundance of individuals; and he took exception to those portions of the paper the conclusions of which were based on palæontological evidence of that kind.

Mr. WHITAKER said that good sections had been revealed by the new railway from Winchester to Newbury, showing the presence in that district both of the Melbourn Rock and of the Chalk Rock. He was prepared to accept the views of the authors as to the erosion of the Chalk strata. He had himself failed to recognize the Chalk Rock at Dover. He could not agree with Prof. Seeley as to the existence of false-bedding at the Cherry-Hinton pit, thinking that the structure taken as false-bedding is a superinduced structure allied to jointing. This structure is found at a particular horizon at many places and in rather clayey chalk. It was very difficult to use the palæontological zones in the mapping of the Chalk. The Chalk Rock is now being worked in the Midland Counties for road-metal, and more pits are now in it than formerly. The Chalk Rock was distinguished palæontologically by the occurrence of Gasteropoda, so rare generally in the Chalk.

Mr. TOPLEY asked for information as to the ground for taking the line of the Melbourn Rock as the base of the Middle Chalk, instead of the Belemnite-Marls, which are said to be above the line of erosion. While palæontological zones cannot be mapped, hard rocky bands can be mapped, and are of great use to the geological surveyor. They are sometimes of great importance as water-bearing beds.

By means of these hard beds we can trace the anticlinals and synclinals of the Chalk.

Prof. JUDD congratulated the authors on the great value of the work which they had accomplished, and the new light they had thrown on the succession of the beds of the Chalk. He thought the microscopical work of Mr. Hill of great value. At the Richmond Well the 10 feet of Melbourn Rock was found underlain by the remarkable brecciated bed he had described, which seemed to represent the Belemnite-Marls of the authors.

Prof. T. RUPERT JONES agreed that the beds in the Chalk spoken of as "brecciated" were really such. He remarked on the rock made up of single and apparently primordial chambers of *Globigerina*, *Planorbulina*, and *Textularia*. Some of these rocks probably consisted of 90 per cent. of remains of Foraminifera.

Dr. HINDE pointed out the great beauty of the sections exhibited by Mr. Hill; many of the rocks appeared to be almost completely made up of organisms.

The PRESIDENT stated that he doubted the existence of false-bedding at Cherry Hinton. He did not think that erosion necessarily implied elevation in the case of the Chalk, because the lowering of barriers during subsidence might allow stronger currents to act.

Mr. HILL said that green-coated nodules do not occur in the representative of the Chalk Rock, but the structure of the rocky layers seen in thin sections under the microscope is similar at Dover. The beds which occasionally present a "brecciated" appearance in the zone of *Belemnitella plena* more commonly show a structure which he and Mr. Jukes-Browne were led to regard as nodular.

19. *On ADDITIONAL EVIDENCE of the OCCURRENCE of GLACIAL CONDITIONS in the PALÆOZOIC ERA, and on the GEOLOGICAL AGE of the BEDS containing PLANTS of MESOZOIC TYPE in INDIA and AUSTRALIA.*
By W. T. BLANFORD, Esq., LL.D., F.R.S., Sec. G.S. (Read March 24, 1886.)

THE two subjects mentioned in the title of this paper are accidentally connected, the evidence of contemporaneous origin in certain Indian and Australian beds that contain plants of Mesozoic types being strongly supported by peculiar physical characters believed to be due to the action of ice. The last number of the 'Records of the Geological Survey of India,' contains several contributions to the history of the question, and these appear to me to form an addition to our knowledge of general stratigraphical geology of importance sufficient to justify my calling the attention of the Society to them. The subject is one to which I have given much attention in past years, and which I have discussed at various times, and this will, I trust, serve to excuse my writing upon it, although I have no new observations of my own to produce.

The principal papers to which I wish to call attention are, first, one by Mr. Richard Oldham entitled "Memorandum on the Correlation of the Indian and Australian Coal-bearing Beds," chiefly giving the results of a visit to Australia by a geologist who had had the advantage of seeing some of the Indian Gondwána beds; and, secondly, one by Dr. W. Waagen, with the title of "Note on some Palæozoic Fossils recently collected by Dr. H. Warth in the Olive Group of the Salt Range." A paper by Mr. Griesbach on rocks near Herat, and a recent observation of Mr. R. Oldham's in Northern Rajpútána, furnish some additional facts of value.

Before proceeding to notice the new data contained in these papers, it will be useful to point out as briefly as possible the previous state of our knowledge. As is well known, three great groups of beds, chiefly of freshwater origin, in three countries bordering on the Indian Ocean—namely, the Karoo formation of South Africa, the Gondwána system of the Indian peninsula, and the Coal-measures and associated beds of Australia—present remarkable points of resemblance in mineral character, fossil contents, and the rarity or absence of bands containing marine fossils. Roughly, these various great groups are thus classed, minor subdivisions being omitted:—

SOUTH AFRICA.	INDIA.	AUSTRALIA.
Stormberg.	Upper Gondwána. { Cutch and Jabalpur. Kota-Maleri. Rajmahal.	} Upper plant-beds of Queensland, &c.
Beaufort.	Panchet.	Wianamata.
Konap.	Damuda. Karharbari.	Hawkesbury (glacial). Newcastle. Upper marine beds (glacial).
Ecce (glacial).	Talchir (glacial).	Stony-Creek beds. Lower Marine beds (glacial).

With the higher of these beds we are not at present concerned: some of them in India and Australia are proved to be of Jurassic age by the association of marine fossiliferous strata, and I have elsewhere* shown what an extraordinary resemblance exists between the geological features of the South-African and Indian formations. Turning to the lower series, the first noteworthy point of similarity is the presence in all of coal-seams with a flora containing closely allied or identical species, the nearest allies of which are found, in Europe, in rocks of Mesozoic and, for the most part, of Jurassic age. The next feature to be noticed is the occurrence in all these regions of boulders supposed to have been transported by ice †.

In Australia alone marine fossiliferous formations are intercalated towards the base of the plant-beds. Species of *Orthoceras*, *Spirifer*, *Conularia*, *Fenestella*, and other fossils of typically Carboniferous affinities are found both above and below certain coal-beds, known as the Stony-Creek beds. Dr. Feistmantel, to whom we are indebted for the best and most recent description of the Australian fossil flora ‡, records from the Stony-Creek beds one species of *Næggerathiopsis* (a cycad), four of *Glossopteris* (a fern), one of *Annularia* and one of *Phyllothea* (Equisetaceæ). All of these genera, except *Annularia*, are found in the overlying Newcastle beds, and also in the Damuda series of India; and most of the species are either identical with Newcastle forms or very closely allied.

This intercalation, though clearly proved by the publication of sections from coal-pits by the Rev. W. B. Clarke § in 1865, and though supported by the evidence of every geologist who has visited the beds (and the number is considerable), has been doubted or rejected by many palæo-botanists. It is scarcely necessary to say that it is fully confirmed by Mr. Oldham. Merely because of the singular unwillingness on the part of some of the best writers on fossil botany to admit the force of evidence that has long since convinced geologists, it may be useful to quote Mr. Oldham's words. After referring to the doubts that had been thrown upon the observations of the Rev. W. B. Clarke and other geologists, and to the suggestion by their opponents that the apparent superposition of Carboniferous marine beds upon strata containing *Glossopteris* &c. must be due to inversion or faulting, he proceeds thus:—

“Such a conclusion, however, could not be allowed by any one who had seen the ground where these beds are exposed. The section is fortunately easily accessible by the Great Northern Railway starting from Newcastle, and the beds are well exposed in the frequent cuttings. There are two exposures of these lower Coal-measures on opposite sides of an anticlinal, one at Stony Creek, two miles west of Branxton, and the other at Greta, ten miles further

* Rept. Brit. Assoc. 1884, p. 705.

† For details and references see ‘Manual of the Geology of India,’ chapter v. Feistmantel, ‘Palæontologia Indica,’ ser. ii., xi., xii., Rec. G. S. I. 1880, p. 250 Oldham, J. A. S. B. liii. p. 187.

‡ Palæontographica, 1878-79; Pal. u. mes. Flora im östl. Australien.

§ Trans. Roy. Soc. Victoria, vol. vi. p. 27, pl. 2.

west. At both places the dip is moderate and steady, to east-south-east at Stony Creek, to west-north-west at Greta; at both places the section is practically continuous, and the marine beds may be traced dipping under the coal-seams, and a short way above them again reappearing. The reappearance of the seam on the opposite side of the anticlinal and the absence of any duplication of the seam are conclusive against any theory that the appearances are due to inversion or strike-faults; while, if further proof were necessary, it would be found in the fact that both at Stony Creek and Greta shafts have been sunk through the marine beds into the Coal, and at the former place through it into more marine beds, thus clearly showing that the Coal-measures are interbedded with the marine beds."

It is unnecessary to enter into the question of the relationship between the fossil floras of India, Australia, and South Africa. Full details will be found in the papers already quoted. A brief history of the glacial evidence may, however, be useful.

The boulder-beds of Talchir were first distinguished in Orissa by my brother and myself in 1856. The suggestion was then made that these beds afforded evidence of ice-action*, because boulders of large size (several have been measured exceeding 6 feet in diameter) occur very often in fine silt, and water in sufficiently rapid action to move the boulders would have swept away the silt instead of depositing it. The boulders in the Talchirs are almost always rounded, probably by torrents, and as the beds are entirely destitute of marine remains, there is every probability that the transporting agent was river-ice.

For many years the theory remained without confirmation, and the boulder-bed, everywhere occupying the same position as the base of what had, in course of time, come to be generally known by Mr. H. B. Medlicott's name of the Gondwana system, was traced throughout a wide area in Bengal and the Central Provinces. At last, in 1872, Mr. F. Fedden† had the good fortune, west of Chanda, to come upon polished and striated surfaces, both on the boulders themselves and on the underlying rock. The late Dr. Oldham, who was in the neighbourhood, immediately on hearing of the discovery, visited the spot and extracted a well-striated boulder‡.

At the base of the Karoo beds in South Africa a boulder-conglomerate has also been found, and its glacial origin pointed out by Dr. Sutherland§ and others. From the description this formation is wonderfully similar to the Talchir bed, but the boulders are not rounded. Dr. Sutherland suggested that this Ecce bed might have been contemporaneous with the Permian breccias of England, described by Sir A. Ramsay||. My brother, Mr. H. F. Blanford¶, in

* Mem. G. S. I. vol. i. p. 49.

† Rec. G. S. I. 1875, p. 16.

‡ Mem. G. S. I. vol. ix. p. 324. This boulder has just been sent to the Indian and Colonial Exhibition to be opened in May at South Kensington.

§ Q. J. G. S. vol. xxvi. p. 514.

|| Q. J. G. S. vol. xi. p. 185.

¶ Q. J. G. S. vol. xxxi. pp. 529, 530.

1874, pointed out that the Talchirs were probably contemporaneous with the Ecça beds.

In 1861 the late Dr. T. Oldham noticed the resemblance between specimens from the lower marine beds of Australia and the Talchir beds of India. He pointed out that not only are both bluish-green silty beds, but that they further resemble each other in the presence of pebbles and large rolled masses in fine silt. This point of resemblance was noticed by my brother, Mr. H. F. Blanford*, but has not generally been alluded to in the discussion of late years†, probably because it had never been confirmed by any one who examined the beds *in situ* until Mr. R. Oldham did so.

In 1866 Dr. A. R. C. Selwyn and the late Sir R. Daintree‡ found a bed containing boulders of considerable dimensions at a spot called Bacchus Marsh in South Australia. The bed yielded some fossil plants allied to *Glossopteris*, and described by Prof. McCoy as *Gangamopteris*, a genus found also in the Australian Newcastle beds and in the Talchir and Damuda series of India.

In 1878 Mr. C. S. Wilkinson§ discovered large transported boulders in the Hawkesbury series. Dr. Feistmantel|| classed this and the Bacchus-Marsh beds as contemporaneous with each other, and also with the Indian Talchir and the South-African Ecça beds.

I believe the above are the most important links that had so far been forged in the chain of evidence, and I now proceed to the additional information just obtained.

In Mr. R. Oldham's recent visit to Australia, he has ascertained that striated pebbles and boulders occur in the Carboniferous marine beds both above and below the Stony-Creek beds. He says:—"Blocks of slate, quartzite, and crystalline rocks, for the most part subangular, are found scattered through a matrix of fine sand or shale, and these latter beds contain delicate *Fenestellæ* and bivalve shells with the valves still united, showing that they had lived, died, and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks now found lying side by side with them. These included fragments of rock are of all sizes from a few inches to several feet in diameter." Mr. Wilkinson had seen in these same beds boulders of slate &c., the dimensions of which might

* *L. c.* p. 534.

† Mr. Oldham appears surprised at my not having mentioned this observation of his father in my reply to Dr. Feistmantel (*Rec. G. S. I.* 1878, p. 104). I was well acquainted with the observation, but I felt and still feel doubtful whether similarity in mineral character can be used as evidence of age, and I do not attach much importance to deductions as to physical characters unless made from examination of the beds in the field. It must be remembered also that no evidence of glacial action in the beds of New South Wales was then available.

‡ Report on the Geology of the District of Ballan, Melbourne, 1866, p. 10. I take from Mr. Oldham's paper this and the next reference to Australian literature.

§ *Trans. Roy. Soc. N. S. W.* vol. xiii. p. 105.

|| *Rec. G. S. I.* 1880, p. 250.

be measured in yards. Mr. Oldham found fragments well smoothed and striated as if by a glacier, and he is inclined to believe that the fragments of rock were derived from icebergs.

Nor are these boulder-beds confined to the locality mentioned north of Sydney. Similar deposits are shown by Mr. Oldham to occur at Wollongong to the south and in the Blue Mountains to the west, and again far to the northward in Queensland. Mr. Oldham also thinks, and I thoroughly agree with him, that the Stony-Creek beds, and not the much later Hawkesbury, are the equivalents in time of the Bacchus-Marsh beds of Victoria. The evidence of ice-action in the Hawkesbury beds is fully accepted by Mr. Oldham, though not regarded as evidence of glaciation so extensive as that which affected the underlying series*.

Thus throughout Eastern Australia, from Queensland to Victoria, there is found evidence of ice-transport in beds belonging to the Carboniferous period. The Australian marine Carboniferous beds have usually been considered of Mountain-Limestone age; but I learn from Dr. Waagen, who has made a special study of the Carboniferous fauna in connexion with his description of that found in the Salt Range of the Punjab, that the Australian marine Carboniferous fossils are of somewhat later date, corresponding approximately to the Coal-measures of Western Europe and to the *Fasulina*-limestones and their associated beds in Russia.

It is very remarkable that, at the very time when Mr. Oldham was engaged in obtaining evidence of glacial action in Carboniferous times in Australia, Dr. Waagen's attention was called to similar evidence in Northern India. The two lines of research were absolutely independent of each other, neither writer being aware of the other's studies, and therefore the circumstance that both, from widely different data, come to the same conclusion as to the age of the Lower Gondwâna is one of those extraordinary coincidences which rarely occur except when a real scientific discovery is made. As already mentioned, both papers appear in the same number of the Indian Geological Survey Records.

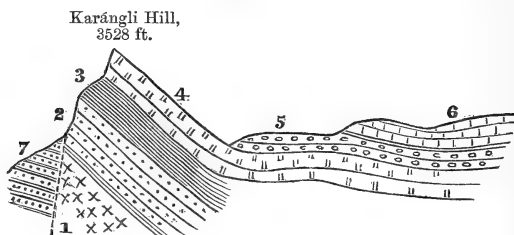
In the Salt Range surveyed by Mr. Wynne and described by him in the fourteenth volume of the Memoirs of the Geological Survey of India, and in the continuation of the range to the westward beyond the Indus, described by the same geologist in vol. xvii., boulder-beds have been found in several places and are described in the works mentioned. One of the most important occurrences is in the eastern part of the range, near the Khewra salt-mines. Here the bed consists of dark shales filled with large boulders of granite, syenite, porphyrite, quartzite, and other hard rocks of unknown derivation. Mr. Wynne, when he surveyed the Salt Range, had very little if any acquaintance with the Lower Gondwâna; but Mr. Theobald, who had a good knowledge of the Talchir beds, at once recognized the

* In the Hawkesbury series angular boulders of shale, of a kind also interbedded, are found in the sandstone. They occur of all sizes up to 20 feet in diameter, with their stratification at all angles to the dip of the sandstone.

similarity of the boulder-formation in the Salt Range, and he obtained from it a roughly rounded fragment of red granite*, polished and striated on three sides, the direction of the striation being different in each case. This boulder is now in Calcutta.

The bed just mentioned has hitherto been considered part of the "Olive Group" of Wynne, and classed as Cretaceous. The relations of the beds may be illustrated by the accompanying section, copied from Mr. Wynne's sketch of Karángli Hill †, the locality from which Mr. Theobald obtained the boulder just mentioned.

Section through Karángli Hill. [From the 'Memoirs of the Geological Survey of India,' vol. xiv. pl. xv. fig. 19.]



1. Salt Marl; 2. Purple sandstone; 3. Dark shales with *Obolus*; 4. Magnesian Sandstone; 5. Olive Group; 6. Nummulitic Limestone; 7. Tertiary Sandstone.

Nummulitic Limestone occurs at the top, resting upon the Olive Group, the uppermost portion of which is fossiliferous, and contains locally, amongst other fossils, *Cardita Beaumonti*, a characteristic fossil, in Sind ‡, of a stage that is certainly older than any recognized Tertiary horizon, and must probably be classed as very high Cretaceous. Beneath this fossiliferous band there is a considerable thickness of sandstone, containing no fossils except some ill-marked bivalves, and then comes the boulder-bed. The *Cardita-Beaumonti* beds, Olive sandstone, and boulder-bed form the "Olive Group" of Mr. Wynne.

Beneath the boulder-bed there is, in places, a band of thin-bedded sandstones and bright red clays, known as the Pseudomorphic Salt-Crystal Zone, on account of the pseudomorphs of cubical salt-crystals found on the surface of the sandstone. This bed is unfossiliferous and may be neglected. The next in descending order, the "Magnesian Sandstone," is equally unfossiliferous, but it is much more important. It is unquestionably Palæozoic; for, further to the westward, it passes beneath another unfossiliferous bed, the "Speckled Sandstone," which there underlies the Carboniferous *Productus*-limestone. Both Speckled Sandstone and Carboniferous Limestone, it must be understood, thin out to the eastward §. Thus it is mani-

* Rec. G. S. I. 1877, p. 224.

† Mem. G. S. I. vol. xiv. pl. xv.

‡ Mem. G. S. I. vol. xvii. p. 34; also Pal. Ind. ser. xiv. pt. 2, p. 16, pt. 3, p. 7.

§ See the diagram given by Mr. Wynne, *l. c.*, opposite p. 69.

fest that either the beds between the *Cardita-Beaumonti* zone and the Magnesian Sandstone represent all the geological sequence from Lower Carboniferous or even older to Upper Cretaceous, or else that one or more breaks, representing vast lapses of time, occur in the sequence.

Here, as elsewhere in the Salt Range, we are assured by all observers, there is the most marked parallelism and apparent conformity in all the beds*. In the absence of fossils, the only clue to subdivisions of the sequence is in changes of mineral character. There is thus no *a priori* reason, so far as the description leads us, why a break should not exist in the middle of the Olive Group; and, according to Waagen's view, a great break does occur here.

This, however, is not the only instance of boulder-beds occurring in the Salt Range. Two other instances, at least, occur. One of these is in the "Speckled Sandstone" just mentioned as occurring at the base of the *Productus*-limestone; the other, apparently the most important of all, is to the west of the Indus, in beds immediately beneath the *Productus*-limestone. These two are evidently on nearly the same horizon, and were, I believe, regarded by Mr. Wynne † as identical. Polished and striated blocks were observed by him ‡ in the bed west of the Indus.

Before proceeding further, it is essential to mention that the *Productus*-limestone of the Salt Range is divided by Dr. Waagen into three stages, the two upper of which he classes as representing the Permian, and the third as the equivalent of the upper part of the European Coal-measures §, and that, in his introduction to his work on the *Productus*-limestone fossils ||, he includes the Magnesian Sandstone (and of course the Speckled Sandstone overlying the Magnesian Sandstone) in the *Productus*-limestone system. Indeed, he especially insists on the close connexion of the Speckled Sandstone with the lower beds of the *Productus*-limestone ¶.

In the neighbourhood of Choya Saidan Shah (near Karángli and the Khewra salt-mines) Dr. H. Warth, a mining-engineer in the service of the Government of India, found, about the beginning of last year, a marine fossil in what he then supposed to be a pebble of the boulder-bed. The fossil was a *Conularia*, and the nodule in which it occurred was at first supposed to have been brought from a distance. But Dr. Warth subsequently obtained numerous additional specimens in similar nodules, and ascertained that these nodules were confined to a thin layer at the top of the boulder-bed, and this layer he traced over an area exceeding ten square miles. This discovery, and also the circumstance that all the nodules are of about the same size and of an oval form, led to the conclusion (which,

* This is very remarkable, as it appears to show that throughout all geological time from the date of the Salt Marls (older Palæozoic) to Eocene and perhaps later, there was a complete absence of disturbance in this area. Yet for a considerable portion of the time the tract appears to have been on or near a coast-line.

† Mem. G. S. I. vol. xvii. p. (236) 26.

§ Rec. G. S. I. 1886, p. 32.

¶ Rec. G. S. I. 1886, p. 32.

‡ Ibid. p. (239) 29.

|| Pal. Ind. ser. xiii. p. 3.

however, is disputed*) that the nodules were not pebbles, but concretions.

Dr. Waagen, to whom the fossils were sent for examination, found 10 recognizable species amongst them. Of these, 2 *Serpulae* and a Lamellibranchiate mollusk, referred with some doubt to *Atomodesma* (*Mytilidae*), are new. A *Nucula* and a *Discina* also occur, but not sufficiently well preserved for accurate specific determination. The more important identifications are:—

Bucania, cf. *kattaensis*, Waagen.

Conularia laevigata, Morris, common.

C. tenuistriata, M^cCoy.

C. cf. *irregularis*, Kon.

Aviculopecten, cf. *limæformis* (Morris).

Conularia laevigata, *C. tenuistriata*, and *Aviculopecten limæformis* are found in the Carboniferous beds of Australia, *Conularia irregularis* in the Mountain-Limestone of Belgium, *Bucania* (a genus allied to *Bellerophon*) *kattaensis* in the lower stage of the *Productus*-limestone of the Salt Range. There can be no question of the fauna being Carboniferous, whilst the fact that only one species, and that not identified with certainty, is known from the Salt-Range *Productus*-limestone, renders it probable that these fossils indicate a slightly different age from that of any of the fossiliferous beds previously known in the locality. This age cannot be newer (for it is absurd to suppose the fauna to be supra-Permian), so it must be rather older. This is the view taken by Dr. Waagen, and he shows how the appearance of a Carboniferous bed, rather older than the known *Productus*-limestone, beneath the *Cardita-Beaumonti* beds at this spot may be accounted for. In starting from the west the *Cardita-Beaumonti* beds are found resting, first on Jurassic beds, then on Triassic, then on the *Fusulina*-beds of the lower *Productus*-limestone, and finally on the *Conularia*-band of the boulder-bed. This last is precisely where the Speckled Sandstone should crop out. Dr. Waagen concludes that this boulder-bed of the eastern Salt Range is the same as that in the Speckled Sandstone of the western portion and as that west of the Indus, and that all are approximately of Coal-measure age, that is, contemporaneous with the boulder-beds shown by Mr. R. Oldham to be so extensively developed in Eastern Australia.

There is, however, a difficulty to be overcome. Mr. Wynne, who surveyed the Salt Range in detail, and is consequently entitled to speak with much authority on the geology, in a recent paper not yet published, but of which a summary is given in the 'Geological Magazine' for March 1886, and also in letters that I have received from him, questions the concretionary nature of the nodules, and states that he has evidence of their being transported†. He particularly

* I will refer to this presently.

† Specimens which Mr. Wynne was so good as to send to me for exhibition at the meeting bear out this view. One unmistakable pebble contains a *Conularia*, the shell of which is intersected by the worn surface of the pebble. But

mentions that a rolled specimen of *Conularia* was sent to him by Dr. Warth, who, if I understand rightly, now considers the nodules to be transported pebbles. Mr. Wynne is also of opinion that the east Salt-Range boulder-bed is on a different horizon from that to the westward.

I am in hopes that this difficulty will be cleared up very shortly, and that the locality will be examined by Mr. Oldham or some other officer of the Indian Geological Survey. Meantime, I think it will be well to await further information. The evidence as to the boulder-beds in the western Salt Range is unaffected by the position of that in the eastern; and if the latter be of later age there will be evidence of two glacial epochs in Northern India, instead of one; though it is difficult to avoid a suspicion that all these evidences of a low temperature are on the same general horizon.

The reason why no one has hitherto been induced to connect these Salt-Range boulder-beds with the Talchirs is, I think, first, because there was no connecting link known, and the distance at which they occurred from each other, between 700 and 800 miles, rendered any attempt to connect them by means of physical characters rather wild speculation; and, secondly, because whilst the age of the western Salt-Range boulder-beds was generally understood to be infra-Carboniferous, that of the Talchirs was scarcely admitted to be so old as Permian. In fact I was almost alone in contending for its Palæozoic age, Dr. Feistmantel having classed it as Triassic. The light now thrown upon the age of the Salt-Range boulder-beds, however, is supplemented by another discovery of Mr. Oldham's, who has corrected a faulty observation of my own.

The most north-western occurrence of the typical Talchir beds with which I am acquainted is in the Nerbudda valley, near Hoshungabad. Far to the westward of the main Gondwana area in Central India some representatives of the Upper Gondwānas are found in Cutch, associated with marine Jurassic strata. The base of the system is not seen, the lowest beds, which are of Bathonian age, being on the verge of a great alluvial tract which conceals all inferior strata. Scattered outcrops, both of the marine and plant-bearing beds, are found emerging here and there from the sands of the Indian deserts north of Cutch, as far north, at all events, as Jesalmir.

In a hurried traverse that I made of the desert in 1876 I found near Pokaran, between Jodhpur and Jesalmir, a well-developed boulder-bed, resting in one place on a grooved and striated surface of the Archæan rocks. It was impossible to determine the position of this boulder-bed without further exploration: the only associated formations were the Archæan Malāni felsites, porphyries, syenites, &c., clearly inferior, and some red sandstones, which I suspected—correctly, as has since been found—to be Vindhyan (probably very old Palæozoic). It appeared to me, however, as if the sandstones

other specimens do not look rolled; the surface is irregular, as if weathered, and amongst these weathered specimens is that which Dr. Warth regards as rolled.

were higher in the series than the boulder-beds; but naturally my hurried observations, made in marching rapidly through a country where only here and there a patch of rock emerges from beneath the blown sand and alluvium, were neither satisfactory nor conclusive. I am not surprised to hear that Mr. Oldham has now ascertained that the boulder-bed is above the Vindhyan, that it is extensively developed, that it forms the basement-bed of these western representatives of the Gondwánas, and, in short, that it is shown by its character and position to be a representative of the Talchir beds.

A glance at the map of India will show that the locality in North Rajputána is nearly equidistant from Hoshungabad in the Nerbudda valley and the Salt Range of the Punjab, and not far to the westward of a straight line between the two.

Still another observation remains to be added. Mr. Griesbach, who is attached as geologist to the mission engaged in laying down the Russian and Afghan boundary, found*, more than a year ago, in the neighbourhood of Herat, greenish sandstones and shales with boulders at the base of a great plant-bearing system containing, he says, *Vertebraria*, a typical Damuda (lower Gondwána) plant. The boulder-bed he recognized at once as Talchir, and he insists on its resemblance to the Ecca beds of South Africa, a similarity due partly to the association of basaltic rock in both cases.

In a subsequent paper he gives further details, and states† that the boulder-bed rests conformably on marine Carboniferous beds. I cannot find any clear evidence as to the position of these beds in the Carboniferous; amongst the fossils are said to be *Productus semireticulatus*, *Athyris Royssii*, *Fenestella*, &c., but both the Brachiopoda have a wide range, and of course the determinations are made without means of accurate comparison; indeed Mr. Griesbach especially states that his notes are merely rough descriptions. Dr. Waagen speaks of the marine beds as Lower Carboniferous; and very probably they are of that age, like the limestones further west in the Elburz. If this be the case, the geological position of the boulder-bed may probably be identical with that in the western Salt Range. But I think it will be well to await further details before coming to any decided conclusion.

The importance of the observation lies chiefly in the fact that if the beds at Herat are really equivalents of the Indian Gondwánas, a great step has been made towards the connexion of the Indian beds, the position of which has so long been problematical, with the typical geological sequence in Europe. As Mr. Griesbach points out, the Herat plant-bearing beds probably represent those of Russian Turkestan and those of the Elburz and Armenia.

Although it was impossible to overlook the remarkable evidence of ice-action previously recorded from South Africa, India, and Australia, I have feared hitherto to attach too much weight to it

* Rec. G. S. I. 1885, p. 62.

† Ibid. 1886, p. 54.

as evidence of synchronism, and in one case, in the supposed proof that the Bacchus-Marsh and Hawkesbury beds were contemporaneous, reasoning from glacial evidence certainly led to a false conclusion. I must say I always felt doubtful about this particular case, and it was partly this which in the last note I wrote on the subject led me to remark, with reference to the supposed synchronism of all the various beds, that it would be very unwise to insist too much on the coincidence. The great addition made to the area over which boulder-beds have now been traced, tends very strongly indeed to support the view that all are really contemporaneous or nearly so, and that the Ecca beds of South Africa and the Talchir beds of India are of the same geological age as the Carboniferous strata of Eastern Australia, and approximately equivalent to the Coal-measures of Western Europe*. At the same time there is no improbability in a recurrence of glacial conditions during at least a considerable portion of the Carboniferous period; and to such recurrences may perhaps be attributed the glacial evidence observed in the Hawkesbury beds of Australia and the Permians of England and Germany. This, however, only overcomes part of the difficulty that arises. One of the great puzzles is to explain why, at a time when the cold, in winter at all events, in 16° north latitude, was sufficiently intense to admit of boulders being carried by ice into large river-valleys or lakes, a much richer vegetation appears to have flourished in far higher latitudes in Europe†.

Mr. R. Oldham, in a recent paper, written, however, before he visited Australia, and before much of the evidence now procured was available, suggested a great alteration in the position of the earth's axis; but I am doubtful whether the position suggested by him for the pole in Central Africa would dispose of the difficulty, and I am inclined to think it better to await more information before attempting to map out the area affected. The idea of glacial action in past times, apart from the subrecent glacial epoch, is novel to geologists in general, and it is very possible that information will accumulate when attention has been more generally drawn to the facts recently ascertained.

There is, however, one point to which attention should for a moment be called, and that is the connexion between the occurrence of a great glacial epoch at the close of the Palæozoic era and the

* I do not employ the terms Upper and Middle Carboniferous, because it is by no means certain what such terms imply. In my own opinion, it is a mistake to divorce the Permian from the Carboniferous, of which, when all are represented by marine beds, the Permian forms the upper series; but in this matter the interests of science are in competition with local convenience.

† The coal-plants found so abundantly in Bear Island, Spitzbergen, and Grinnell Land are chiefly from the Ursa beds, which are much older than the European Coal-measures, though one stage in Spitzbergen is said to be equivalent to the uppermost Coal-measures. No Arctic coal-plants are known, so far as I am aware, of the same date as that now assigned to the boulder-beds of India, Australia, and South Africa. Also it should not be forgotten that identity of fossil plant-remains does not prove beds to be of contemporaneous origin. At the same time the absence of glacial evidence in past times amongst Arctic lands must not be forgotten.

enormous change that took place in all life, vertebrate and invertebrate, animals and plants, in the interval between Upper Palæozoic and Lower Mesozoic times. Despite all the discoveries of Palæozoic types in the Trias, and of Mesozoic genera in Upper Carboniferous or Permian, that have taken place in the last forty years, the fact remains as distinct as it was when it formed the subject of Prof. E. Forbes's Presidential Address to the Society in 1854, that a greater change in forms of life takes place between Permian and Trias than between any other two consecutive systems in the whole of geological time. If the views above expressed be correct, and if during part of the Carboniferous period an excessively low temperature prevailed, some explanation of the change may be found. The alteration in marine life at the close of the Palæozoic period appears to have been enormously greater than anything produced by the last glacial epoch, the effects of which, indeed, may be said scarcely to have influenced the tropical seas, although in places, as in India, the modification of the land-fauna and flora has in all probability been extensive. The circumstance that the temperature towards the end of the Palæozoic era must have been lower than in the Pleistocene epoch, may account for the occurrence of boulder-beds of the former date in tropical and subtropical countries.

Under the impression that the Indian Damudas were of later date than the Newcastle beds of Australia, the idea has been suggested by several writers* that the European Mesozoic flora originated in Australia in Palæozoic times, was driven to the equator by the increasing cold in the Permian epoch, and thence spread again to the northward in Mesozoic times as the temperature improved. This may be partially the fact, but it is not necessary to invoke the aid of migration to the same extent. It is at least equally probable that a considerable tract of Southern Asia † in Carboniferous times formed part of a continuous land area extending to Australia on one side and to South Africa on the other, that this land area was absolutely severed from all the countries in which the Coal-measure flora existed at the time, and was subjected to a much colder climate. It is unnecessary to remark that the Coal-measure flora was long since proved not to have required a tropical climate for its development. The distinction between the two floras is in all probability due to long isolation—to a difference, in short, of geographical areas with a distinct biological history, or of what are generally known as botanical regions.

DISCUSSION.

The PRESIDENT remarked upon the wide range of the paper. In the case of some communications hardly more than two or three Fellows could be expected to take part in the discussion; but in the

* Manual Geol. India, Introduction, p. xxxvi; Oldham, J. A. S. B. vol. liii. pt. 2, p. 195; Waagen, Rec. G. S. I. 1886, p. 37.

† Gondwana plants, mixed up in an extraordinary manner with each other and with European Rhætic types, have been found in Tonquin. Zeller, Bull. Soc. Géol. France, sér. 3, vol. xi. p. 456.

present case, with a paper dealing with India, South Africa, and Australia, and which raised such questions as the value of fossil plants as evidence of geological age, and of the recurrence of glacial conditions, it was to be expected that the discussion would be wide, lively, and possibly warm.

Dr. SELWYN said that conglomerate beds similar to those referred to at Bacchus Marsh were very largely developed in Gipps Land, where they formed mountains 3000-4000 feet high. *Lepidodendron* and some other indistinct fossil plants were found in the associated strata, but none of the Bacchus-Marsh forms. He thought it possible the conglomerates were of the same age, though on the evidence of the plants they had been considered different. Glacial action may have operated in their formation, though he had not observed any evidence of it.

The much discussed Stony Creek section is paralleled in British Columbia, where a Tertiary flora is interbedded with a Mesozoic marine fauna.

Mr. CARRUTHERS remarked that this was not a question of stratigraphy, but as to the value of botanical and zoological data in determining the age of strata. It appeared to him that the remains of plants might indicate the age even more than those of animals. It was not a question of the replacement of the Carboniferous flora of Europe by a flora of the same age but of a different facies, for, though the *Lepidodendra* of Australia were Devonian, there was a Carboniferous flora of the same type as that of Europe in South Africa (Karoo beds), consisting of *Lepidodendra*, *Sigillaria*, *Calamites*, and Ferns; and in addition there was present this later *Glossopteris*-flora with a Mesozoic facies. In South Africa, India, and Australia this flora is placed, on zoological evidence, at a lower level than it ought to occupy.

Mr. LYDEKKER wished to call attention to two points bearing on the present paper. In the Kashmir Himalaya the Kuling series seems to represent the Lower *Productus*-limestone, and beneath it there is a considerable thickness of traps underlain by the Blaini conglomerate, which closely resembles a glacial boulder-bed. This boulder-bed appears to be the equivalent of that in the Salt Range; and other boulder-beds lower down in the series point to the prevalence of still earlier glacial conditions. Mr. Lydekker also called attention to the homotaxy of the groups of the Gondwānas, and showed a perfect agreement between the age indicated from the consideration of the vertebrate fossils and that arrived at upon other grounds by Dr. Waagen and Mr. Oldham. The sequence thus obtained indicates representative groups from the age of the Lower Jura (Kota) to that of the Carboniferous (Talchir). In South Africa, also, we get a complete series from the Jura to the Palæozoic.

Prof. T. R. JONES remarked that in the case of the Stormberg he regarded the presence of *Lepidodendron* as a myth. The Karoo beds contain vertebrate remains, including highly organized Reptiles, and it seemed to him that these furnished better evidence than a flora. He referred to the evidence adduced by the late Mr. Stow

of glacial action in the lower part of the Karoo beds, which buried glaciated surfaces on rocks probably of Archæan age.

Prof. DUNCAN said that it was very satisfactory to know that the recent discoveries strengthened Mr. Blanford's original opinions regarding the Palæozoic age of the Lower Gondwánas. Having had the advantage of studying the rocks and fossils of the Gondwána series in the Museum of the Royal Indian Engineering College, he (Prof. Duncan) was impressed with the necessity of approaching the study of the age of the Lower Gondwána series from above, for there were no fossiliferous deposits beneath them. There were Purbeck-Wealdens in Kachh, and also beds containing a Jurassic flora placed between marine strata, and the Mollusca were often identical specifically with those of the European type. Then the Rajmahal beds must be lower than the Oolitic and the facies of the plants was Liassic. The succession below was through a great depth of sedimentary rock with thick plant-beds, and the Upper and Lower Damudas had a different flora from the Rajmahal above and the Karharbari beds of the Talchirs below. The flora was Mesozoic in facies, but there were such forms as *Neuropteris valida* and many Equisetaceæ, which gave a kind of European Palæozoic appearance. He considered that the animal remains must be considered of greater classificatory value than the floras. With regard to the glacial question, he considered that the Talchir boulders were the remains of the moraines on the flanks of mountains which had sunken.

Rev. E. HILL remarked that when people change the axis of the earth, they do not change its shape. Hence, for glacial conditions to thus arise in the southern localities alluded to, one pole of the earth must have been somewhere about the middle of the Indian Ocean, and the equator about where England now is. Dr. Croll claimed that there was a Glacial period in the Carboniferous epoch.

Prof. SEELEY thought it was an exceedingly doubtful proceeding to attempt correlation of beds on the ground of traces of glaciation. It seemed to him desirable that we should get fuller evidence that the glaciation referred to in the paper had really existed. A few scratches appeared to be doubtful evidence. The pebbles and boulders described by the author were in some cases several feet in diameter and rounded; and in how many cases were there those smoothed surfaces with striæ which furnished unmistakable evidence of glacial conditions? He referred to other causes of such phenomena, and even of scratches, quite independent of glaciation.

As regarded the question of fossils as indicating the age of deposits, he thought that we are not justified in taking such a plant as *Glossopteris* as characteristic of a particular geological period. He referred to the case of *Trigonia* as indicating the mistakes into which we may easily be led by attaching too much importance in this respect to particular types, and maintained that, however good such a mode of settling the age of deposits may have been in past time, with our present knowledge it is liable to lead to a delusion. From the reptiles found in the Indian rocks referred to, no one would have any reason for regarding them as referable to a sharply

defined epoch. The time has not yet come for the correlation of rocks by means of their fossil contents; and this is especially the case with deposits which seem to hold a position intermediate between the Palæozoic and Mesozoic series.

Mr. DE RANCE admitted the important testimony adduced in support of the notion of the occurrence of Glacial epochs in Palæozoic times. But he wished to ask the author how he proposed to explain the presence, throughout the extreme northern regions, of Silurian, Devonian, and Carboniferous rocks, containing fossils identical with those obtained in similar rocks in Europe. At the time of the deposition of the Carboniferous Limestone, the Lias, and Oolites, there seems to have been a continuous sea over the North Pole. There was no evidence in these rocks of difference of temperature; the conditions seem to have been the same until we arrive at the Cretaceous epoch, in which indications of climate first appear.

The AUTHOR, in reply, admitted that some of his points were fairly open to question, but he begged to say that upon these he had by no means pretended to speak decidedly. With regard to the change of position of the earth's axis, he had remarked only that this explanation had been suggested. He was quite prepared to join issue with Mr. Carruthers on the question whether plants or marine animals should decide as to the age of the deposits referred to. Prof. McCoy, who thought the plants Mesozoic, was convinced as to the Carboniferous age of the marine fossil animals in Australia; so also were Prof. Morris and Prof. De Koninck. He maintained that there is no known instance in which marine animals referred to a certain age in one place are found differently arranged elsewhere, whereas with plants the case is quite otherwise. With regard to the doubts raised as to the pebbles and boulders being transported by glacial action, he said that such masses, sometimes measuring six feet in diameter, occurred scattered through a very fine silt, and he knew of no other agency than that of ice by which boulders of that size could have been so deposited.

20. *On the BASEMENT-BEDS of the INFERIOR OOLITE of GLOUCESTERSHIRE.* By E. WITCHELL, Esq., F.G.S. (Read February 24, 1886.)

DURING the last twenty years very little has appeared in the Journal of the Geological Society upon the Inferior Oolite of Gloucestershire. Prior to that period the Journal contains several valuable papers on that formation by able geologists, among whom I may mention the names of the Rev. P. B. Brodie, Dr. T. Wright, Professor J. Buckman, Professor E. Hull, and Dr. Holl. In addition to these papers we have the Memoir of the Geological Survey by Professor E. Hull, 'The Geology of Cheltenham,' and Dr. Lycett's 'Geology of the Cotteswold Hills,'—works which have served as guides to the Cotteswold geologist to the present time. Indeed the work done between the years 1847 and 1860 was of such great extent and excellent character that it seemed as if there was nothing more to do in the Cotteswolds except, perhaps, to make from time to time some addition to the lists of fossils of the district; but after working over the Inferior Oolite of the Cotteswolds nearly a quarter of a century, and going carefully over the work of my predecessors, I am of opinion that another paper at least is required upon the lower beds of that formation before they can be thoroughly understood. My reasons for this opinion are:—(1) That the beds called "Pea Grit" in the Leckhampton section by Hugh Strickland, which name was adopted by Dr. Wright and the Geological surveyors, include in that term—erroneously, as I think—all the beds occurring between the Pea Grit proper and the Cephalopoda-bed of the sands, which beds are shown in some sections to be more than thirty feet in thickness. (2) That the use of the term "Pea Grit" in the way I have mentioned has led to confusion in the description of the beds extending over a large portion of the Cotteswold area. (3) That the Pea Grit proper has a much greater extension over that area than has hitherto been supposed to be the case.

If we examine the lower beds of the Inferior Oolite in the typical section at Frocester Hill, beginning with those immediately overlying the Cephalopoda-bed, we see that they consist of brown sandy limestone in two or three beds, and above these some beds of crystalline limestone about 10 feet thick, and beds of fine-grained limestone about 50 feet. These beds are thus described by Dr. Wright; but Dr. Lycett, while giving a similar description of the brown sandy beds, refers to the others as "beds of oolitic limestone used as a freestone quarry." In the section at Haresfield Hill we see similar beds, and on reference to the published sections find a nearly similar description of the Cephalopoda-bed, the brown sandy limestone-beds, and the oolitic limestone or freestone. At Leckhampton Hill we again see these beds, but find on reference to the published works that they are described as "pea grit," yet they are the same beds

as at Frocester and Haresfield Hills. If they are called Pea Grit in one section and something different in the others confusion is created, and a stranger is likely to find it difficult to understand the sequence of the beds however carefully examined.

The earlier geologists have fully described the Pea Grit and the beds below, and the extension of the latter from Cleeve Hill to Frocester Hill; but they appear to have imagined that the oolitic limestone at Frocester and Haresfield Hills was part of the freestone series *above* the Pea Grit, and that the brown sandy limestone near the base represented the Pea Grit and ferruginous pisolitic beds of Leckhampton; but it will be shown that if the Pea Grit is traced from Leckhampton to Birdlip, and thence along the escarpment of the Cotteswolds, it is found to pass over Haresfield Hill on a horizon 20 feet above the brown beds, and is continuous for several miles beyond. This is explained by the accompanying diagram (fig. 1).

Dr. Lycett says * "from Cleeve Hill to Birdlip Hill, an extent of about eight miles, would seem to include the limits of the pisolite upon the western face of the Cotteswolds;" and, again, "the ferruginous beds when no longer pisolitic extend southwards in the Cotteswolds in reduced and constantly diminishing importance;" and he mentions that at Haresfield Hill they consist of "about 12 feet of hard ferruginous sandstone in four or five beds having a tendency to a concretionary structure at the junction of the beds, and at Frocester Hill the hard brown bed which overlies the ammonite bed is the sole representative of the ferruginous Oolite."

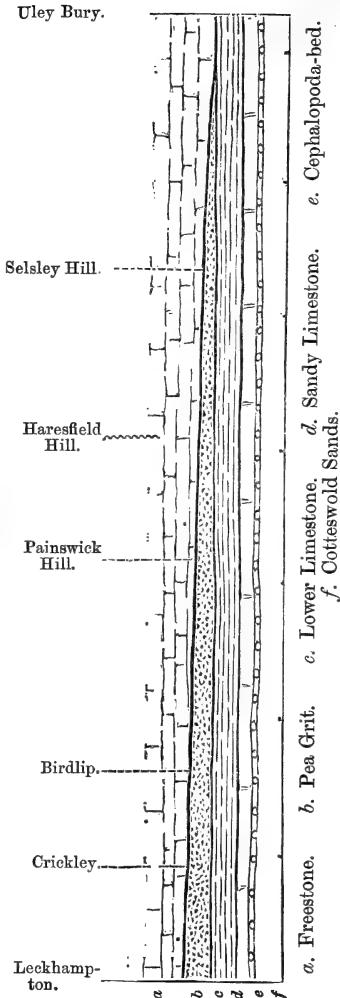
Dr. Wright, in his section at Haresfield, does not allude to Pea Grit at all, although he is describing the identical beds which he has called "Pea Grit" at Leckhampton; and in his description of these beds at Frocester Hill he refers to the shelly and pisolitic seams which traverse them as resembling those in the Pea Grit—a remark which, I think, he would not have made if he believed he was describing beds which he had, in the section of Leckhampton Hill in the same paper, called Pea Grit †. It is, I think, fair to assume that neither Dr. Lycett nor Dr. Wright regarded the oolitic limestone of Frocester and Haresfield Hills as part of the Pea-Grit deposits, and that the existence of these deposits at Haresfield Hill, 20 feet above the hard ferruginous sandstone and separated from it by white oolitic limestone of that thickness, was overlooked by them, neither did the extension of the Pea Grit over the Stroud area, south of Haresfield, appear to have attracted their notice; on the contrary, Dr. Lycett, in describing the sections of Inferior Oolite at Selsley Hill and Longfords, near Nailsworth, directs attention to certain bands or seams of marl of which the one in Selsley Hill contained *Terebratula plicata*, and includes them in the *middle* or white freestone division of the Fimbria stage, the Pea Grit of Leckhampton constituting the *lower* division ‡. He was evidently unconscious of the extension of

* Cotteswold Hills, p. 38.

† Quart. Journ. Geol. Soc. vol. xii. pp. 294 *et seq.*

‡ Cotteswold Hills, pp. 39 *et seq.*

Fig. 1.—Diagrammatic Section from Leckhampton to Uley Bury. Distance 16 miles.



the Pea Grit so far as Selsley and Nailsworth, but this extension is, however, beyond all doubt. I have traced it along the escarpment at the following points: Painswick Hill, Horsepools Hill, Haresfield Hill, Randwick Hill, Selsley Hill, and Coaley Wood adjoining Uley Bury, the last-mentioned place being 13 miles distant from Birdlip (fig. 1). In the valleys which intersect the Cotteswolds in the neighbourhood of Stroud the beds can also be traced; sections of Pea Grit can be seen at Stroud, Rodborough Hill, Nailsworth, Horsley, and in the Golden Valley above Chalford; but in the latter locality the beds are only pisolitic or, rather, marly limestone. The section at Longford's Mill, near Nailsworth, contains a bed of Pea Grit in which the grains are in a soft marly paste, overlying a bed of pisolitic limestone charged with several species of *Nerinea*, the whole being about five feet thick. At Horsley it is a pisolitic limestone with pockets of Pea Grit; its thickness is about three feet. At Coaley Wood it is reduced to nine inches, and has lost its ferruginous character except at its base, where there is a thin layer of ferruginous sand. The three last-mentioned places are the furthest points from Birdlip towards the south-west at which the Pea Grit has yet been observed. Wherever it preserves its ferruginous aspect it presents a striking contrast to the beds above and below; and as the difference in structure is equally striking, there need not be any confusion in

accurately defining these beds as well as the oolitic limestone beneath and the freestone above.

The underlying or basement beds, which I propose to call the Lower Limestone to distinguish them from the various limestone beds above the Pea Grit, are to be seen in numerous exposures on the slopes of the Cotteswold Hills, especially where the Cephalopoda-bed is seen, as at Cam Down near Dursley, Coaley Wood, Frocester Hill, and Haresfield Hill, also at Birdlip, Crickley Hill, and Leckhampton, and in most of the valleys near Stroud.

The beds next above the Cephalopoda-bed are usually brown sandy limestones in two or three beds, varying in thickness from five feet at Cleeve Hill, near Cheltenham, to seven feet near Stroud and Frocester Hill. The beds are locally fossiliferous near the base, but much less so in their upper parts. Upon these brown beds there are several beds of oolitic limestone, which are well described by Dr. Wright, in the Frocester-Hill section, as "a coarse, light-cream-coloured, gritty, crystalline oolite, traversed at intervals by shelly layers extremely crystalline. A great part of the rock appears to be composed of the fragments and plates of Crinoidea, the plates and spines of Echinidæ, and comminuted fragments of the shells of Mollusca." In the upper portion these beds approximate to a freestone character, and are well described by Dr. Wright, in the Haresfield section, as "a close-grained freestone resembling the same bed at Leckhampton, but becoming rather flaggy in the upper part."

There is very slight difference between these oolitic limestones, as they appear in the sections at Frocester Hill and Haresfield Hill, at Crickley Hill, near Leckhampton, and in the Stroud valleys; they preserve the same lithological character throughout, except that at Leckhampton they appear to be somewhat coarser in structure, approaching the pisolitic character, hence their being described in that section as Pea Grit. One of the beds in the Stroud area is remarkable for its great thickness; in several quarries it varies from 10 to 15 feet, a feature quite unusual in the lower Oolites and is altogether different from the pisolitic character, which is that of a rubbly rock. Upon the upper surface of these limestone beds, which is usually quite plain and somewhat worn, the valves of a small oyster are attached; they are numerous but not so as to be contiguous. I have found them in several localities, and they appear to extend over the whole of the Stroud area.

The thick bed of limestone contains seams of shelly detritus, and occasionally rather large rolled grains and small quartz pebbles, rolled pieces of corals and Bryozoa, indicating a littoral deposit; but the general character of the rock is that of a white oolitic limestone. If the presence occasionally of seams of coarse grains is held to justify the inclusion of these beds in the Pea Grit or pisolitic limestone, known as the ferruginous deposits, the greater part of the Inferior Oolite must be so included, because the whole of the beds contain locally coarse oolitic grains; this is especially the case in the Oolite-marl.

The following sections will show the general character of the beds:—

Section at Crickley Hill taken at the Western end of the Quarry.

(1) Pea Grit.

	ft. in.
1. Brown pisolite	4 0
2. Brown pisolite	3 0
3. Brown pisolite, thickness variable, about	5 0
4. Coarse oolite subdivided by pisolite	7 0
5. Brown coarse pisolite	5 0
6. Pisolite beds	11 0

(2) Lower Limestone.

7. } Four beds of oolitic limestone composed of shelly	
8. } detritus, fragments of spines of Echinida, and	
9. } oolitic granules	8 6
10. }	
11. Fine-grained oolitic limestone	1 9
12. Coarse-grained oolitic limestone	5 0
13. Coarse brownish oolitic limestone	2 6
14. Hard brown compact oolite	5 0

(3) Sandy Limestone.

15. } Four beds of ferruginous sandy limestone	6 3
16. }	
17. }	
18. }	

(4) Cephalopoda-bed, not exposed.

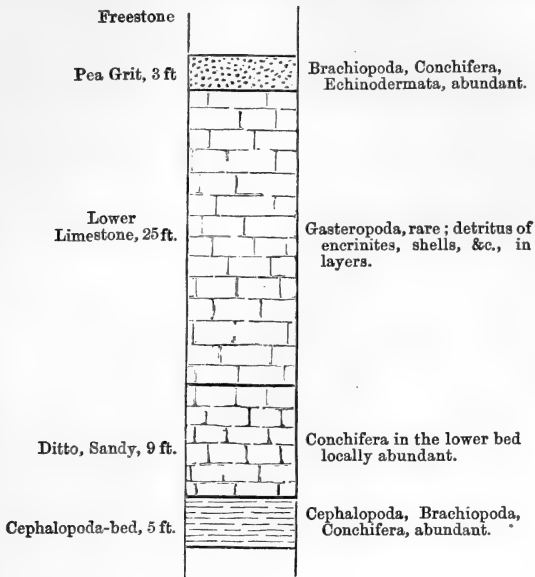
In this section it will be seen that the Pea Grit and pisolitic beds are 35 feet thick, and the limestone beds 22 feet 9 inches and 6 feet 3 inches. The beds 7–10 are persistent over the Stroud area, and are almost identical in structure with the Crystalline Oolite at Frocester Hill.

General Section at Ruscombe near Stroud.

	ft. in.
1. Freestone	10 0
2. Pisolite	3 0
3. Pisolite, pisolites detached	0 3
4. Freestone with reddish-brown sand in the partings... ..	10 0
5. Oolitic limestone, a very thick bed, hard and semi-crystalline in the upper part, mainly composed of shelly detritus, fragments of coral, spines, &c. Upper surface level, covered with small valves of <i>Ostrea</i> and marks of boring	16 0
6. Three brown sandy limestone beds	9 0
7. Cephalopoda-bed	

The thick bed (No. 5) may be seen in Standish Park, on the north-western slope of the hill, also in Horns Valley, near Stroud, 4 miles distant.

Fig. 2.—General Section of the Lower Beds of the Inferior Oolite in the Stroud Area of the Cotswolds. Scale $\frac{1}{16}$ in. = 1 ft.



As the result of my observation I give the following summary of these basement-beds (fig. 2):—

1. Pea Grit, including the pisolitic beds, well developed in the Cheltenham area and at Birdlip, becoming thinner at Painswick Hill, and having a thickness of 3 to 5 feet in the Stroud area, extending to Uley Bury, where it appears as a thin band having nearly lost its ferruginous aspect.
2. Several beds of white oolitic limestone having layers of free-stone alternating with layers of detritus of Crinoidea, Echinida, and shells, and containing locally small quartz pebbles; in places highly crystalline and containing, in the Stroud area, a bed of considerable thickness—20 to 30 feet.
3. Brown sandy limestones in several beds, locally coarse ferruginous gritty beds, very fossiliferous in the lower portion, lying on the Cephalopoda-bed—5 to 9 feet.
4. Cephalopoda-bed.

These beds show, on close inspection, that the oolitic structure does not commence with large pisolites as hitherto supposed. In the sandy limestones (3) the oolitic structure is almost absent, but in the overlying white limestone (2) it becomes more apparent, and the upper beds are still more oolitic and more nearly resemble the free-stone. The large grains of the Pea Grit come in suddenly and

show a well-marked dividing line between the pisolitic beds and those beneath.

If the lithological character of the Lower Limestone differs so greatly from that of the Pea Grit, its palæontology presents a still more striking difference. There are few fossils to be found in the beds of white oolitic limestone, as the meagre list given below will show; but there is a fossiliferous zone in the lowest bed of the sandy limestone or zone of *Ammonites opalinus*, although the character of the rock is such that it is impossible to extract the fossils except at great cost of time and labour. The upper beds of white oolite have yielded a few minute Gasteropods, some of them almost microscopic; but these are the only results of very diligent search. On the other hand, a very large number of Gasteropoda, Brachiopoda, Echinodermata, and Conchifera came in with the Pea Grit, many of which are of large size and peculiar to the deposit; for instance, the genus *Nerinea* is represented by six species, three of which have not been hitherto described. The advent of so many species of this genus (*Nerinea*), and of another species in the Yorkshire oolite of contemporary age, is remarkable, if this was the first appearance of the genus, as stated by Woodward, and furnishes an additional reason for separating the Pea Grit from the Lower Limestone beneath it.

The following fossils have been collected from the White Oolitic Limestone.

Ceritella acuta, <i>Mor. & Lyc.</i>	Monodonta Lyellii, <i>Archiac</i> (young).
Cerithium geniculatum, <i>Ter. & Jour.</i>	Nerita hemisphærica, <i>Römer</i> (young).
—, n. sp.	Rissoina, n. sp.
—, sp.	Kilvertia, n. sp.
— quadricinctum, <i>Goldf.</i>	Turbo, sp.
—, var.	Brachytrema, n. sp.
—, sp.	

DISCUSSION.

Mr. ETHERIDGE remarked upon the difficulty of following the paper without a knowledge of the district. Mr. Witchell had determined the position of certain new beds, which Dr. Wright and others had overlooked. He further commented on some confusion arising from the use of the terms Pea Grit and Pisolite. Most of the escarpment-sections are obscured by talus. He commented on the thickness of the Pea Grit at Birdlip, and expressed his belief of the value and correctness of Mr. Witchell's views for the Stroud area. He also spoke of the microscopic characters of the fossils of the beds described.

Mr. HUDLESTON observed that the object of this paper was to describe an important series whose position had been misunderstood. Its distinctive character had not been recognized, and it had been confounded with the Pea Grit, from which it differed both lithologically and palæontologically. Both Dr. Wright and Dr. Lycett, it seems, had misunderstood the position of this Lower-Limestone series in the Stroud area. He could thoroughly endorse Mr. Witchell's

position so far as his experience of the Stroud area was concerned, and had been much struck with the poverty of the main mass of the Lower Limestone, except in small Gasteropoda.

Rev. P. B. BRODIE spoke of the bone bed at the base of the Cephalopoda bed at Crickley, near Cheltenham; and drew attention to the occurrence of "bone beds" at the junction of one formation with another.

Mr. WALFORD remarked that Mr. Lucy speaks of the diminution of the pisolites vertically at Birdlip. He mentioned the fact of a ferruginous limestone at Bourton-on-the-Water resting on some sands above the Upper Lias. He objected to the term Lower Limestone.

The PRESIDENT, whilst expressing regret at the cause of the Author's absence, observed that it was only fair to Dr. Wright to remark that some of the confusion with respect to the confounding of the Pea Grit with the lower beds had arisen since his time. The several divisions of the Inferior Oolite had been named after what were supposed to be their principal members.

21. *On two RHÆTIC SECTIONS in WARWICKSHIRE.* By the Rev. P. B. BRODIE, M.A., F.G.S. (Read February 24, 1886.)

A FEW years ago a very interesting section of the Rhætic beds, the best yet laid open in the county, was exposed in a cutting on the railway at Summer Hill, between Stratford and Alcester, near the village of Binton. The line runs nearly east and west; the strata are much disturbed at the east end of the cutting, and have a considerable dip to the south-east. On the east the Insect-bed, probably the bottom one of the series, with insect remains, viz. wings of *Libellula* and elytra of Coleoptera, is seen, the section dipping towards Binton Hill, and in that direction, at the extreme end, being on a level with the line. This is underlain by the freestone and *Estheria*-bed, succeeded by a considerable thickness of Rhætic black and grey shales, some parts of which are highly charged with pyrites and loaded with the usual characteristic fossils. A band of blue nodular stone in the shales probably represents the *Pecten*-bed. I did not observe the Bone-bed; but if any opening had been exposed towards Bidford, on the west, it might have been present where the underlying New Red Triassic marls come in. Apparently there was no sandstone, as at Copt Heath, near Knowle, at the base of the shales with *Schizodus cloacinus* (*Pullastra arenicola*); but on the whole these shales are several feet thicker than in any other sections hitherto exposed in Warwickshire. The Rhætic fossils are better preserved here than usual, certainly better than at Wainlode and Westbury cliffs in Gloucestershire; many of the shells, though, as usual, very fragile, retain their test. They include the following genera and species:—

Fish-scales.	<i>Myophoria postera.</i>
<i>Avicula contorta.</i>	<i>Pteromya crowcombeia.</i>
— <i>solitaria.</i>	<i>Placunopsis alpinus.</i>
<i>Cardium rhæticum.</i>	<i>Natica Oppelii.</i>
<i>Pecten valoniensis.</i>	<i>Trochus?</i>
<i>Schizodus</i> (<i>Pullastra</i>) <i>cloacinus.</i>	<i>Ophiolepis Damesi.</i>
<i>Modiola minima.</i>	

Unfortunately I could not ascertain the exact position of *Ophiolepis* in the section even after a careful search, as the specimen was found in a small piece of dark pyritous shale containing *Avicula contorta* lying loose in the cutting. At Westbury Cliff the original discoverer of this radiate in England informed me that he obtained it from a bed of black shale about two inches thick underlying the shales with *Cardium rhæticum*, and midway between the *Estheria*-bed and the upper of the two large bone-beds. My late friend Dr. Wright places it in the *Cardium*-shales just above the upper bone-bed, and immediately below the grey *Avicula-contorta* shales. As *Avicula contorta* and another small bivalve are associated with the *Ophiolepis* at Summer Hill, it would appear to be somewhat higher up in the series than at Westbury, and the shale at the latter place is much harder and darker, and more compact, with no pyrites, than at the

former locality. This characteristic Ophiuroid seems to have a wide range, having been found in the Rhætics in South Wales, Gloucestershire, Leicestershire, and originally in Germany. It has also been noticed higher up in the White Lias near Rugby.

Another section, of considerable interest, more recently obtained was at Snitterfield, a village three miles north of Stratford-on-Avon, and about seven miles north-east from Summer Hill. Three rather singular remnants of the Rhætics were observed, and when I first visited the spot I found the usual black and grey shales with the characteristic fossils exposed on the spoil-bank which had been brought up from excavations made to form a tunnel connected with the water-supply for the town of Stratford. A tunnel was driven, and borings carried down to a considerable depth, the deepest being fifty feet from the surface, in order to form square wells, and in the heading the conduit was constructed to convey the water from the brook to the reservoir at a lower level. The upper shaft nearest to Snitterfield Brook, as seen in the horizontal section before the meeting, was sunk through a considerable thickness of drift, 46 feet consisting of blue clay resting on sand and gravel; the former runs out and disappears at about 200 feet distant from this shaft. In the lower shaft, at King's Lane, nearest the reservoir towards Stratford, the upper blue clay is not so thick, and is succeeded by red marl with a thicker bed of sand and gravel below; but the total thickness of the drift there is 48 feet 6 inches. The blue clay contains abundant flints, pieces of chalk, and stems of *Extracrinus*. The gravel is made up of numerous derivative pebbles of quartzite, some probably lower Silurian, as elsewhere in Warwickshire, and various other old unfossiliferous rocks, and among them is a fragment of a large Liassic Ammonite. The gravel is largely quarried near Snitterfield for the roads, and contains numerous Lias and Rhætic fossils and similar pebbles. In both the shafts the drift lies immediately on the Triassic red marl. A small patch of Rhætic black shale, nearly horizontal, was met with in the shaft nearest the reservoir overlying the Triassic marls.

At the shaft at King's Lane another, but smaller remnant of black papery shales occurred resting on green marls. The largest mass of these shales was passed through in the shaft near Snitterfield. The Rhætics here appear to have been much denuded and irregularly deposited. The entire thickness of these shales has not been ascertained, but probably is not very great for reasons stated. The green marls contain large nodules of gypsum. I was able to determine the presence of the Rhætics at this spot by finding in the shales the usual characteristic fossils, viz. :—

Avicula contorta.
 ———— *solitaria*.
 ———— ————, var. *falcata* *.

Cardium rhæticum.
Schizodus cloacinus.

* Not having observed this form anywhere before in the Rhætics, and thinking it might be new, I presented some specimens to the South Kensington Museum (Natural History), and my friend Mr. Etheridge pronounced it to be new in the British Rhætic formation.

The specimens were numerous as usual, but the species few, and very fragile; they were not so abundant or well preserved as at Summer Hill; but owing to the small quantity thrown out, there was less chance of finding many fossils. The only place where I have observed any limestone with Rhætic shells is at Brown's Wood, but no section is exposed there, the pieces of stone lying loose in the fields.

I have previously * shown the presence of the Rhætics in other parts of the county, *e. g.* at Copt Heath, near Knowle, Brown's Wood near Henley-in-Arden, and in a railway-cutting near Kineton. The extension of this series is now indicated still further in a southerly direction, and it probably regularly underlies the lower beds of the Lias in their course through Warwickshire.

I am indebted to the kindness of Mr. Willcox, the intelligent engineer of the waterworks, who is also a geologist, for information about the tunnel, and for the plan showing the section of the heading No. 1.

DISCUSSION.

Prof. BOYD DAWKINS said that the section at Snitterfield was precisely similar to one described by himself near Watchet. Near Watchet the Rhætics dip at a considerable angle, and are repeated by faults. The speaker doubted the erosion of the lower beds, and thought that the appearance of deposition in pot-holes was due to faulting. So far as he had seen, there was no change of dip between Rhætic and Trias such as would indicate unconformity.

Mr. ETHERIDGE also had never seen true unconformity between the Trias and the Rhætic. The finding of *Ophiolepis* was most important, as showing the connexion with the same beds in Germany.

Mr. USSHER, from an examination of the relations of the Rhætic beds between Alcester and Worcester, pointed out that the tea-green marls formed, as do the buff marls of Somerset, a definite and easily distinguishable junction with the red marls, and therefore he considered that for mapping-purposes they should be included in the Rhætic. He did not think the section exhibited by the Author could be taken as any indication of unconformity; the only appearance of unconformity he was acquainted with was at Newark, which a more searching investigation might prove to be otherwise explainable. He inquired if the *Cardium-rhæticum* shales, to which the Author has assigned a definite position, were taken to represent the White-Lias limestones, and whether the top bed (sunstone) was represented in the sections.

The PRESIDENT pointed out that the main question on which difference of opinion had arisen was whether there was evidence of the Triassic beds having undergone erosion before the deposition of the

* "On a further extension of the Rhætics in Warwickshire, Leicestershire, Nottinghamshire, Rutland, Lincolnshire, Yorkshire, and Cumberland," 'Warwickshire Naturalists' Field Club Proceedings,' March 1875.

Rhætic; he asked if the Rhætic beds seen in the shafts could possibly have slipped down from the elevations in the neighbourhood, or whether there was any chance of the Rhætics being transported masses in drift.

The AUTHOR said the Snitterfield section was drawn below the surface by a very good engineer and geologist, but he had not himself been able to examine all the details. He saw no reason for believing that the beds were not in place, but he could not speak quite positively. In reply to Mr. Ussher the Author observed that the sun-bed (limestone) did not occur in Warwickshire, and was confined to Somersetshire.

22. *On GLACIAL SHELL-BEDS in BRITISH COLUMBIA.* By G. W. LAMPLUGH, Esq. (Read April 7, 1886.)

(Communicated by Clement Reid, Esq., F.G.S.)

Part I. VANCOUVER ISLAND.

Part II. THE FRASER VALLEY.

Part I. VANCOUVER ISLAND.

Introduction.—Having occasion to remain for nearly a month in the ‘city’ of Victoria, Vancouver Island, in the autumn of 1884, I had an opportunity of examining the glacial phenomena so finely developed in the vicinity. Not having foreseen that I should visit this place, I had not acquainted myself with the geology of the neighbourhood, so that it was not until after I had left the island that I became aware of the researches of previous observers; and, lacking this knowledge, I spent the greater part of my time in working out for myself what I might very quickly have learned from others. While studying the magnificently glaciated rock-surfaces near the city*, I found it necessary to follow the highly indented coast-line of this part of the island, and, in doing so, found in two places marine shells in the Boulder-clay.

The occurrence of shells in these glacial beds has been previously recorded by Mr. H. Bauerman (Quart. Journ. Geol. Soc. vol. xvi. p. 198) and by Dr. G. M. Dawson (Quart. Journ. Geol. Soc. vol. xxxiv. p. 89). The first-named gentleman merely mentions the presence of “casts of shells (*Cardium* and *Mya*) in a yellowish sandy clay” at Esquimault Harbour. Dr. Dawson, in his excellent memoir, has a fuller, though still brief account, which I will give in its integrity as I believe that it includes all that is at present known of the subject. I will afterwards add my own observations, which I hope may be found to increase the stock of our knowledge by the addition of many particulars, which though perhaps of no great importance, are yet instructive and, for the purposes of comparison, even necessary to us. In the second part of my paper I shall be able to prove a considerable submergence of the Fraser Valley during glacial times, by recording the presence of marine shells in drift-beds more than 50 miles above the mouth of the river.

Dr. G. M. Dawson’s Description.—Dr. G. M. Dawson in describing the glacial deposits of south-eastern Vancouver, gives the following account of the shells:—

“Mr. Bauerman mentions the occurrence of casts of *Cardium* and *Mya* in these deposits, an observation which for a long time I was unable to confirm; but eventually several localities were discovered where molluscous remains are tolerably abundant. These

* For some record of my observations on these glaciated rocks see ‘Proceedings of the Yorkshire Geological and Polytechnic Society’ for 1885, vol. ix. pt. 1, pp. 57-70.

shells were not noted in the lowest portions of the drift. They are generally contained in hard fawn-coloured sandy clay, almost without stratification, and are frequently quite decayed and crumbling, though found with the valves united in the position of life. Granitic fragments included in the clay are also very frequently more or less decomposed, and sometimes completely rotten, showing that carbonated surface-waters here long acted on the mass since its elevation. This action may probably account for the comparative scarcity of the shells, while its continuance for a period somewhat more prolonged would without doubt have resulted in their total removal. The beds so affected are at a height of only a few feet above the sea; and this, coupled with their resemblance in texture to many inland drift-deposits, suggests one means of accounting for the apparently complete absence of marine remains over areas which on other evidence appear undoubtedly to have been at one time submarine, but which from their elevation must have been much longer exposed to the percolation of surface-waters.

“The following species have been recognized among the fossils hitherto found:—

Cardium islandicum.	Natica clausa (probably).
Leda fossa.	Balanus crenatus (probably).
Saxicava rugosa.	

“In localities where the upper sandy and gravelly layer of the drift is not developed, the change from deep-water to littoral conditions appears to be marked by the rather sudden introduction of carbonaceous matter, changing the clayey deposits from their usual pale tints to dark brown. In some places the marine shells, and especially the *Cardium* above named, appear sparsely in the highest layers of the pale clays; while in other localities, near the present shore-line, the lowest layers of the shell-heaps, and burnt stones used by the Indians in cooking, coincide with those of the brown earth, showing apparently that the last movement of elevation by which the land attained about its present level was rather sudden, and that habitation by a race resembling the present natives followed closely on the termination of the glacial conditions.

“The general appearance of the deposits of this part of Vancouver Island, resting, as they do, on planed and polished rocks perfect in every detail and necessitating glacier-action for their explanation, and yet consisting of water-bedded and often current-driven materials mingled in places with sea-shells, leads to the belief that they were formed along the retreating foot of a glacier which had extended some distance beyond the margin of the land. The withdrawal of the ice may have been caused or accompanied by subsidence; and some species of shells must have followed its front pretty closely in its retreat. The somewhat irregularly terraced form of the deposit is probably due to action during emergence; and the general tendency of many facts is to show that a slight sinking of the coast is at present in progress or has lately occurred.”

Glacial Shell-beds at Esquimault, V. I.—Proceeding now to my own observations, I will first describe some sections I examined at Esquimault, V. I.

Esquimault is a small village about four miles west of Victoria, so favourably situated on a deep land-locked inlet, known as Esquimault Harbour, that it has been selected by the British Government as the site of their chief naval station in the North Pacific. To increase its utility in this direction the construction of a large dry dock was commenced some time ago on the eastern shore of the peninsula on which the village stands; and though at the time of my visit work was suspended, owing to the failure of the contractors, it had so far progressed that the excavation was nearly completed, almost the whole of the floor-bed laid, and the side-walls partly raised.

As the bottom of the excavation was from 20 to 30 feet below high-water mark, the sections exposed possessed peculiar interest, an opportunity being afforded for studying the beds below sea-level. It was seen that the dock had been excavated along a deep narrow fissure in hard igneous rock, which had been partially filled in and hidden by drift-deposits. The rock was probably a diorite, and the drift consisted, in its lower portion, of a confused mass of gravel, sand, and glacial clay, passing upwards into hard sandy till.

The excavation had been carried on chiefly in the drift-beds, but touched the rock on either side, and also at the landward end of the dock, where the fissure became so narrow as to necessitate the quarrying of its walls.

The bottom of the fissure was not reached, and there remained an unknown thickness of drift below the floor of the dock, a sump-hole sunk down 10 feet from the lowest level being still in clay and gravel*. Along the sides of the fissure the surface of the rock, whether vertical or horizontal, was everywhere beautifully glaciated, except near the entrance to the dock.

The dock has been excavated in a direction slightly crossing that of the gully, which seems to run about W.S.W. and E.N.E. The rock outcrops above the surface and rises in a steep broken ridge close to the northern edge of the excavation, thus marking the limit of the fissure in that direction; while on the other side, though the ground in the immediate vicinity remains low and is much obscured by buildings forming the village, and by dump-heaps, there is reason to think that the rock lies not far from the top.

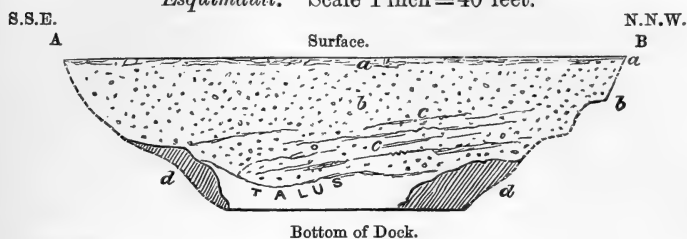
Before these works were commenced, the sea must have encroached somewhat on the drift-beds in the gully, so as to form a short inlet into the land, there being a layer of recent shells and other marine remains above the drifts over the greater part of the sections.

Work having been suspended for some time, the whole of the sections were somewhat obscured by talus; but that which crossed

* This information was given to me by the engineer.

the landward end of the dock was clear except at the base, and was as shown in fig. 1.

Fig. 1.—Section across the Landward End of the Dry Dock, Esquimault. Scale 1 inch = 40 feet.



a. Top soil.

b. Boulder-clay with scratched stones: boulders most plentiful in the upper part of the section, where the clay has weathered to a yellowish grey; below, it is of a bluish-grey tint, and admits streaks of sandy and silty matter (*cc*); shells occur scattered through the lower portion of this section and in *cc*.

d. Hard green dioritic (?) trap, with its surface everywhere beautifully striated grooved, and polished.

There was also another excellent section in the recess which forms the entrance-basin on the north side of the dock, and shells were more plentiful and less disturbed here than in any other part of the excavation. The upper part of this section showed stony Boulder-clay of the usual character; but this seemed to pass downwards into a softer clay, which contained few stones and showed traces of bedding and streaks of sand and gravel. Irregular seams of shells ran through this part of the section, chiefly bivalves with the valves united.

The lengthwise sections were much obscured, but showed shelly Boulder-clay resting, in places, against the sloping sides of the gully on very highly glaciated surfaces, and overlain by the recent sea-bottom, which rose up with a gradual slope from the dock-entrance, where it was about 20 feet below high-water mark.

Across the mouth of the inlet, just within the construction-dam, there was a deep trench which reached a lower level than any other part of the excavation; its section showed nothing but hard sandy till overlain by the recent sea-bottom, here forming a bed of shells two feet thick, many being bivalves of large size. The till, though it did not actually contain shells, was full of little cavities from which shelly matter had been removed, and which could be easily identified as casts of shells of the same species as those found in the other sections.

The Shells.—In their general characteristics these sections did not differ from many to be found along the neighbouring coast-line where drifts overspread or fill up crevices in the solid rock, excepting in the presence of shells. But up to this time I had not found a single shell or shell-fragment in glacial beds, while in these sections they were present in abundance; they were most plentiful along the northern side of the excavation, being most numerous in the

sandy and clayey streaks already mentioned as occurring in the recess near the dock-entrance, and seeming to become gradually scarcer both vertically and laterally as these beds were left. At the landward end of the dock they occurred sparingly in the lower part of the section, scattered through a stony clay with scratched boulders, and were absent altogether from the upper portion, which rose somewhat above sea-level.

On collecting them I soon found that though they were numerous as individuals, only a few species were represented, some of which were well known to me from my researches amongst similar beds on the coast of Yorkshire. The first collection which I made I was obliged to discard, as I found that I had not been careful enough in discriminating between the glacial shells and those from the overlying recent sea-beach which had sometimes been washed down over the sections. Afterwards, taking none except such as I could be certain were imbedded in the clays, I collected the specimens from which the following list has been compiled, the determinations having been kindly undertaken by Mr. Clement Reid, of H.M. Geological Survey, and Mr. Edgar Smith, of the British Natural History Museum.

List of Shells from Glacial Beds at Esquimault, V. I.

Mutilus, sp. (imperfect).	c. Saxicava rugosa, Linn., and var. arctica.
Leda buccata, Steenstr.	Chiton (Katharina) truncatus, Wood (=C. sitkensis).
— arctica, Gray.	? r. Purpura lapillus, Linn.
— pernula, Müll.	r. Buccinum inexhaustum, Verkrüzen.
Nucula inflata, Hancock.	c. Balanus porcatus, da Costa, var. Polyzoa.
Cardium islandicum, Linn.	Spirorbis (on pebbles).
— grœnlandicum, Chemn.	
r. Tellina edentula, Brod. & Sow.	
Mya truncata, Linn.	
— arenaria, Linn.	

Notes.—The shells which were most abundant are marked c, those which were rarest, r.

I am not quite certain that *Purpura lapillus* belongs to the glacial beds; I only found one specimen, and this under somewhat doubtful conditions.

It will be noticed that *Leda fossa*, which is one of the four species mentioned by Dr. G. M. Dawson, is not included in this list. I asked Mr. Reid if he could find this shell amongst the rather numerous *Leda* I submitted to him, and he replied "There is nothing approaching *Leda fossa* in your collection."

In some of those parts of the section which lay below sea-level, where the clays were still saturated with moisture, these shells were found in a very excellent state of preservation, the valves being united and firmly closed as in life, the interior almost or quite empty, and the outer case of the external ligament and the brown epidermis of some of the species still remaining. Indeed, I found specimens which looked fresher than the shells in the overlying

recent deposit, which were already beginning to crumble under the influence of the sun and the weather; and at first I had serious doubts whether such specimens might not in some way have worked down into the bed from above; but I soon saw that this was quite impossible, and, moreover, that most of the species were not represented in the newer deposit. As the shells dried, this "bloom" passed off, and they faded into rather brittle fossils.

This remarkable state of preservation, which was most marked in the seams where the shells were most abundant, was confined to beds which lay some depth below the surface. Upwards the shells became scarcer and more weathered, and they finally disappeared about 10 feet from the surface, so that in the upper portions of the deeper sections there was not a trace of them to be seen. I could not quite decide whether their absence in these cases was entirely due to the decay of the shells, or whether they had never really been present in the topmost layers of the Boulder-clay. There is some reason for entertaining the latter view, for in the section across the entrance to the dock, though, as already mentioned, no shells were to be found in the Boulder-clay, their former presence was clearly demonstrated by their empty casts in the clay; whereas in the higher sections no similar casts could be found. It is possible, however, that in this case casts may also at one time have existed, but have been gradually filled in and obliterated by the weathering of the clay and the percolation of muddy waters.

Dr. Dawson has pointed out the reason for the great difference in the condition of the shells, in one of the passages quoted at the commencement of this paper. The thick forest-growth which has for ages clothed almost every foot of dry land over the whole of the island has accumulated a variable but persistent layer of vegetable soil which has yielded solvents to the waters passing through into the clays beneath, so that wherever there has been a circulation of surface-water through the drifts, the shells and also many of the smaller boulders of felspathic rocks have been softened and crumbled or altogether removed; but where the clays below the surface have stood lower than the sea-level, they have been below saturation-line, and there has consequently been little or no percolation through them. The low-level section near the dock-entrance is a seeming exception; but in it the clays are at the surface, though below sea-level, and it is probable that there has been a slow passage of waters through the upper few feet of the clay, while the decaying matter in the mud of a sea-bottom crowded with life would no doubt furnish acids enough to destroy the shells.

It would be difficult to find a clearer demonstration of the intense effect of slightly varying conditions on the preservation of organic remains, nor a more striking illustration of the manner in which beds have been denuded of their fossils, than is yielded by these sections; for here might be found, within the space of a few yards, shells so fresh that it would have been easy to believe that the mollusk was still within, others so soft and decayed that they

might be rubbed to a paste between the fingers, and others, again, from which every particle of shelly matter had been removed, so that there remained only the casts in clay; and yet they were probably all living at the same moment, have all been imbedded in the same matrix, and have differed only in their distance from the surface.

I think it is probable that the beds in which the shells were so admirably preserved have not been elevated above sea-level since their deposition.

In spite of the position and condition of these shells, I do not think any I found in these sections were in place, that is to say, have lived where they occurred, though I dare say that the description of the beds which I have given above will not be thought to bear out this conclusion very satisfactorily. Yet such was the impression given me by a careful study of the beds, and I believe that the whole mass of drift, including the shells, has been pushed up into the gully by ice in its passage southward across Esquimault Harbour. It is possible that a truly marine deposit may still exist in the deeper recesses of the gorge below the dock-floor, and I was at first inclined to think that some of the stratified seams I examined might form part of such a bed; but as these appeared to be mere patches in till, the shells occurring in nests, and as the bedding dipped steeply *towards* the adjoining rocky cliff—unlikely conditions in a sea-bottom—I think it is safer to consider that the whole of the sections seen have been disturbed and removed by ice. Indeed, if this conclusion be not accepted, I see no other alternative than to regard the whole mass of drift exposed in these sections as of marine origin, since the shells were not confined to the bedded portion, but were scattered through the unstratified mass also, and no line could be drawn between the shelly and shell-less clay.

So far as the irregular distribution of the species was concerned, I might have been examining sections in Yorkshire such as I described to the Society two years ago*; in fact, in many particulars there was an extraordinary similarity to the English beds, so that one had occasionally to look at the surrounding landscape to dispel illusions. *Leda* occurred in one place, *Nucula* in another, and *Cardium* and *Saxicava* everywhere, just as at Bridlington.

Balanidæ coated many of the smaller pebbles, and had sometimes grown so large and thick as quite to overshadow and hide their foundation, but they were often on the underside of the pebble as it lay in the clay and not in the attitude of life. Some of the pebbles which were thus coated were angular chips of rock resembling that found in the neighbourhood. Except in the stratified seams the shells were scattered at random through a rather loose blue-grey stony till (which weathered to a pale yellowish brown at the top), sometimes in separate valves, sometimes with valves united, in the latter case often crushed together and broken. Boulders were decidedly more plentiful and larger in the upper than

* Quart. Journ. Geol. Soc. vol. xl. p. 312.

in the lower portions of the sections, and in the lowest beds seen there were only a few small pebbles, and I could find no shells.

But although the material of which these beds was composed has, in my opinion, been dislodged and pushed forward by the ice, it is difficult to believe that these shelly clays have been the instrument with which the ice has ground and polished the underlying rocks, or that they have formed the *moraine profonde* when this work was being done. I did find instances of rock-grooving in the district in which the substance which lay directly over the polished surface had almost certainly been the means by which the effects were wrought; but this was always a hard sandy grit pressed almost to the consistency of rock, whereas in these sections the material which rested on the glaciated surface was usually the most incoherent part of the drift.

If the neighbouring ground were stripped of its glacial deposits, the fissure, which has probably resulted from the weathering and scouring of a deep master-joint, would be found to cut nearly or quite across the little peninsula separating Esquimault Harbour from Royal Bay. It would be hemmed in on both sides by higher ground, the rocky ridge across the neck of the peninsula east of the village reaching a height of over 100 feet above sea-level, whilst immediately to the west there is hard ground from 50 to 70 feet high. In the low cliff on the outer or western side of the peninsula there is a section showing a narrow crevice in solid rock, filled in with hard glacial clay containing no shells, which may form the prolongation of this gully, though a little out of the line. The waters of the harbour have a depth of from six fathoms in the basin to 9 fathoms at the entrance, while just off the coast in Royal Bay there is a depth of 30 fathoms, with a continued downward slope into the Straits of Juan de Fuca which separate Vancouver Island from the mainland, where the depth exceeds 100 fathoms. There must at some period in glacial times have been a great thickness of ice in the neighbourhood, as Mount Douglas, which lies six miles to the north-east, is 696 feet high, and shows signs of glaciation to its summit.

As already mentioned, the rocks forming the sides of the fissure were beautifully striated, grooved, and polished, both on their vertical and horizontal surfaces, the striæ running nearly in the direction of the walls, and, where these were vertical, rising along them with a slope of about 30°. This shows that the ice must have moved in from the lower ground now forming the harbour, and have passed up the gully in crossing the peninsula on its way to Royal Bay, and in doing so it must have exerted immense pressure on the walls of the fissure. There was an exception, however, to the general glaciation in the steep face of rock abutting on the Boulder-clays on the north side of the dock near its entrance; for here there were no striæ, and the surface of the rock was quite rough and irregular. At this point the gully is wide, and the opposite wall low and hidden; and it seems as though the pressure had been focussed, as it were, on the narrower part of the gorge.

It is noteworthy that it was in this, the most sheltered part of the section, that the shells were most numerous and best preserved, and that the drifts showed the greatest tendency to stratification.

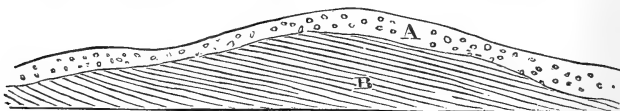
The glaciation of the rock-surfaces could not well have been wrought when the gorge was choked with these deposits, and it seems clear to me that it must have taken place before the deposition of the shelly clay. As the shells bespeak open water, it is therefore probable that there has been a period of intense glaciation followed by a withdrawal or partial withdrawal of the ice, during which an arctic fauna established itself in the waters of the neighbouring fiord, after which the ice has again returned, pushing the sea-bottom up before it, and driving this, mixed with its own detritus, into the position in which we now find it. The distance traversed need not have been more than a few hundred feet, though it is possible that portions may have been carried much further, and in their passage have lost all traces of their marine origin.

Shell-bed in Shoal Bay.—The second locality in which I found shells in the drift was in Shoal Bay, or McNeil's Bay as it seems to be called by the dwellers in the neighbourhood, a little recess in the coast east of Victoria, a short distance beyond the city limit. Here, near the middle of the bay, I noticed shells in streaks of stratified clay amongst grey Boulder-clay on the beach just below high-water mark, close to the foot of the low cliff; they were badly preserved, and I found no species save those already recognized at Esquimault.

Part II. THE FRASER VALLEY.

Leaving Vancouver Island I crossed over to the mainland of British Columbia, and, while walking down the right bank of the Fraser river, I observed marine shells in beds of glacial age some distance from the coast. Following the course of the then unfinished Canadian Pacific Railway, I crossed the Harrison river near its junction with the Fraser. Just beyond, the line makes a detour to the north, to avoid a steep mountain which abuts directly upon the Fraser below the junction of the rivers. This mountain appears to consist of massive igneous rock, but at its foot, along the banks of the Harrison, is a great accumulation of detrital beds, through which the railroad has been carried by a series of cuttings.

Fig. 2.—Section in Railway-cutting on West Bank of Harrison River, British Columbia. Length about 50 yards, height 30 ft.



- A. Red clay, with angular stones, resting unconformably on—
 B. Bedded silts with sand, containing crushed shells, sandy at top*.

In one of these cuttings, where the section was as shown in fig. 2, I noticed some thin streaky layers of crushed shells. These shells

* The lines of shading in this woodcut do not represent the bedding-planes of the silts, which had only a low dip.

were all so shattered that, at the time, I was not certain of their marine origin, but subsequent examination has proved this beyond doubt.

The stratified clay in which the shells were found contained no pebbles, and, though somewhat disturbed, had evidently been deposited where it occurred. A large and beautifully striated boulder of grey granite (10 feet \times 4 \times 6) lay at the foot of one of the sections, and seemed to have slipped out of the clays, but I saw no such boulder in place. The red clay full of rough angular stones, which capped the section, was probably of glacial origin, but might have been an accumulation of talus shed from the steep mountain-slope behind the section.

A little further north there was another cutting about 40 feet deep, in which the section exhibited differed considerably from that shown in fig. 2. It showed—

- A. Rough angular débris of variable thickness, overlying
- B. Thin seam of cross-bedded silts of limited extent, cut out in either direction by A, overlying
- C. Stratified gravel with glaciated blocks.

Here I could find no shells, nor could I be certain that the silt was the same as in the previous section, though the evidence greatly favoured this view.

The next cutting, 100 yards further north, showed nothing but hard till, in a section 50 feet deep.

A little way beyond this, the section (about 60 feet) exhibited only well-bedded and waterworn gravel, through which ran a thin seam of silt, overlying hard stony blue till.

Further on, the upper gravel of the last section became rough and angular; and then an outstanding bluff of the solid rock jutted out to the river, and through this the road had been quarried. At the other side there were no drifts to be seen on the mountain-slopes near the railway, and it seemed to me that the bluff had sheltered the deposits behind it and preserved them from denudation.

Where the shells were found, the height of the railroad above the Harrison river is about 40 feet, and as the Fraser at its junction with the Harrison is not less than 55 miles from its embouchure, these beds cannot be less than 100 feet above sea-level.

The weather was so very wet at the time of my visit that I did not attempt to investigate the bed or trace out its extent, except so far as this could be done from the railroad, as the thick forests which covered the ground on all sides—difficult to pass through at any time on account of the underbush—were extremely disagreeable to go into after so much rain.

Some of the crushed shells which I brought away with me I have submitted to Mr. Clement Reid, and he has recognized amongst them fragments of the following:—

Saxicava rugosa.
Tellina, sp.
Mytilus, sp.

Balanus, sp.
Foraminifera (undetermined).

DISCUSSION.

The PRESIDENT said that probably some geologists would find it difficult to accept the Author's explanation of the presence of the shells in the Boulder-clay.

Mr. CLEMENT REID remarked on the great clearness of the paper, and bore testimony to the close analogy between these deposits and those of Holderness. A new point in the paper was the similarity of the glacial faunas of Vancouver Island and Holderness, whilst the present faunas of the Atlantic and Pacific are so different, showing that an Arctic fauna had been driven southwards into both oceans. He quite corroborated the Author's views as to decalcification, but declined to discuss the question of the origin of the Boulder-clay.

Dr. HINDE commented on the undoubted fact of the former existence of glaciers in this district; but whether the transportation of the shelly clays took place at their second advance after a mild interval, the evidence seemed hardly sufficient to determine.

Prof. BONNEY was sensible of the value of the paper, but thought that the Bridlington beds differed from those described in being portions of masses transported in a frozen condition. He thought it impossible that the shells would have escaped destruction on the Author's theory. He instanced the case of the neighbourhood of Montreal, where a true Boulder-clay overlying ice-worn Trenton Limestone may be traced into a sandy deposit crowded with *Saxicava*, &c.

Prof. SEELEY had found shells in the Boulder-clay of Norfolk and Cambridgeshire, all of which, when not broken, were abnormally thick.

Mr. ROBERT BELL remarked on the fact that nearly all the specimens were bivalves, and a large number of them in pairs.

The PRESIDENT regretted the absence of Mr. Bauerman, who was personally acquainted with the locality described in the paper.

23. ACCOUNT of a WELL-SINKING made by the GREAT WESTERN RAILWAY COMPANY at SWINDON. By HORACE B. WOODWARD, Esq., F.G.S. With Lists of FOSSILS by E. T. NEWTON, Esq., F.G.S. (Read March 10, 1886.)

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|--------------------------------|-------------------------|
| 1. Particular account of Well. | 4. Saline Waters. |
| 2. Lists of Fossils. | 5. Fresh Water. |
| 3. Remarks on Strata. | 6. General Conclusions. |

1. THE Great Western Railway Company being desirous of obtaining a good supply of water for use in their locomotive and stationary engines at Swindon, determined, in 1883, to sink a well. The spot chosen for this undertaking is on the northern side of the railway, and at the western end of the Company's works.

Two shafts have been sunk, very close together—one known as the South Well, to a depth of 246 feet, and the other as the North Well, to a depth of 736 feet 2 inches. The details of the strata passed through in the two sinkings, to the depth of 246 feet, are practically the same, the shafts being 8 feet in diameter and sunk the entire depth. The object of the additional shaft was for convenience in pumping and in carrying away the material excavated. The surface of the ground is 329 feet above the Ordnance datum.

The formations proved in the North Well are as follows (see section, p. 296):—

	ft.	in.
Made ground	8	0
Kimeridge Clay	64	1
Corallian beds	40	1
Oxford Clay and Kellaways Rock....	572	9
Cornbrash	18	3
Forest-marble	33	0
	<hr/>	
	736	2

From a practical point of view this well has not been altogether successful; for, although the promoters did not actually get into hot water, they tapped a supply of luke-warm and very saline water.

The Corallian beds, which occur between the depths of 72 and 112 feet, yielded the first supply of water, which issued at the rate of about 1000 gallons per hour; but neither in quality nor in quantity was it deemed satisfactory. It contained 144 grains of saline matter per imperial gallon.

Water again was met with at the depth of 730 to 736 feet, rising from the Forest-marble at the rate of about 2000 gallons per hour, and having a temperature of 64° F. This water, unfortunately, proved to be much more saline, containing over 2000 grains per imperial gallon, and was therefore utterly unfit for use in the locomotive and stationary engines.

The influx of water put a stop to further sinking. For a time it was pumped away, but since Christmas 1885 the pumping has been discontinued, and the water, which had been kept at 253 feet from the surface (or 483 feet from the bottom of the well), rose eventually, on February 4, 1886, to within 25 feet of the ground-level, or about 304 feet above Ordnance datum.

Early in 1885 the Great Western Railway Company sought advice at the Geological Survey Office concerning the prospects of finding fresh water by deepening their well, and in February of that year Mr. Newton and myself paid a visit to Swindon to examine the rocks and fossils which had been preserved. A large number of specimens had been carefully arranged in a room, with the depths marked on them, and a diagram had been drawn to show the nature of the strata passed through. And these as well as note-books were most kindly placed at our disposal by Captain William Dean, under whose directions the works were conducted. Eventually a large number of fossils, which Mr. Newton desired to examine more minutely, were sent to the Museum in Jermyn Street.

Particulars of the strata in the upper part of the well-sinking were recorded by Mr. W. H. Stanier, and in the lower part (below 460 feet) by Mr. A. R. Elliott, to both of whom we are greatly indebted. The accompanying statement, however, while mainly based on the information furnished by the Great Western Railway Company, embodies all the notes made from a personal and independent examination of the fossils and of the many samples of rock.

WELL AT GREAT WESTERN RAILWAY WORKS, SWINDON.

[Prepared in great part from Notes furnished by Messrs. W. H. Stanier and A. R. Elliott.]

		Thickness.	Depth.
		ft. in.	ft. in.
	Made ground	8 0	8 0
Kimeridge Clay.	Bluish-grey clay, with <i>Ammonites</i> , <i>Belemnites</i> , &c.; grey clay with shells, at depth of 12 feet	42 0	50 0
	Pale grey shelly limestone, <i>Ostrea deltoidea</i>	0 1	50 1
	Grey and brown earthy limestone, with patches of iron-shot grains, rich in fossils	0 6	50 7
	Hard brown calcareous muddy clay	2 0	52 7
	Bluish-grey clay, with seam of grey shelly clay 2 feet from bottom	19 6	72 1
	Alternate beds of hard, light-grey, compact, marly limestone (shelly in places), and thin irregular seams of clay.....	10 4	82 5
	Dull grey marl	0 10	83 3
	Compact pale grey limestone, with shelly layers and bands of pale grey marl.....	0 5	83 8
	Clay.....	3 0	86 8
Corallian beds ("Coral Rag)."	Alternate beds of clay and grey gritty limestones, shelly in places, and irregular; about six bands of rock and five of clay, from 6 inches to 1 foot in thickness	7 3	93 11
	Clay, dark and sandy on top, with seam of stones (? nodules) about the middle.....	4 0	97 11

		Thickness.	Depth.
		ft. in.	ft. in.
	Hard and rather compact grey limestone, shelly and oolitic in places, cavities lined with calc-spar; and calcareous grit, with clay between seams	5 10	103 9
	Sand and slightly calcareous clay, greyish-brown oolitic sandy marl, and hard grey marl with <i>Ammonites</i>	8 5	112 2
	Clay, with grey gritty and slightly micaceous marl, at depth of 120 feet	20 6	132 8
	Hard clay	4 0	136 8
	Shaly clay (water-bearing), with slightly calcareous rock, at depth of 140 feet (? Septarium)	3 6	140 2
	Hard clay	3 0	143 2
	Clay, dry, with calcareous gritty rock at depth of 145 feet, and soft grey shelly calcareous and sandy rock at 160 feet	8 10	152 0
	Clay	1 6	153 6
	Uneven layers of rock	0 6	154 0
	Clay, with Septarium, dense pale bluish-grey, sparry, argillaceous limestone, at 155 feet 3 inches	2 6	156 6
	Rock (probably Septaria)	0 8	157 2
	Clay	0 4	157 6
	Rock (probably Septaria)	0 8	158 2
	Clay, details not recorded		
	" indurated shelly marl at depth of 226		
	" ft. Septaria with <i>Nautilus</i> at depth of		
	" 434 ft. elongated Septaria with iron		
	" pyrites at 456 feet	420 10	579 0
	" Septaria at 460 feet		
Oxford	Greenish-grey shelly clay with Septaria	0 6	579 6
Clay.	Clay	2 0	581 6
	Septaria	0 4	581 10
	Clay	0 4	582 2
	Septaria (one specimen 5 feet in diameter by 1 foot)	0 3	582 5
	Dark bituminous clay	0 7	583 0
	Septaria	0 3	583 3
	Clay	0 5	583 8
	Septaria	0 2	583 10
	Clay	2 11	586 9
	Dark clay, full of small bivalves	0 4	587 1
	Grey clay with shells	4 8	591 9
	Very dense clay, entirely free from fossils ...	3 3	595 0
	Hard light grey shelly clay	5 0	600 0
	Laminated clay	4 3	604 3
	Dark laminated greenish-grey clay, with few fossils	3 6	607 9
	Septaria	0 6	608 3
	Clay	1 2	609 5
	Greenish-grey clay, shelly in places	3 10	613 3
	Dark grey clay, shelly in places	8 0	621 3
	Grey and brown laminated shelly clay	1 6	622 9
	Septaria, shelly, and containing lignite	0 6	623 3
	Dark greenish-grey laminated shelly clay ...	6 4	629 7
	Greenish-grey gritty marl with bivalves	0 7	630 2
	Greenish-grey shelly clay	1 5	631 7
	Sandy clay, with few fossils	0 3	631 10

		Thickness.		Depth.	
		ft.	in.	ft.	in.
	Dark laminated clay, with few fossils.....	6	0	637	10
	Greenish-grey shelly clay (with <i>Perna</i>), and dark unctuous clay	2	3	640	1
	Dark greenish, unctuous, shaly clay, shelly	0	3	640	4
	Slightly calcareous sandstone and grey gritty rock, with loose sand and clay, rich in fossils and iron pyrites.....	2	5	642	9
	Dense laminated and slightly sandy clay, with few fossils, and <i>Septaria</i> (containing water). The lower portion of this stratum (1 foot) shows a decided change to sand...	3	3	646	0
	Greenish-grey gritty sandstone, with few fossils	7	11	653	11
Kellaways Rock.	Greenish-grey calcareous sandstone, few fossils	2	0	655	11
	Greenish-grey clay, shelly in places	0	7	656	6
	Dark greenish-grey, unctuous, shaly clay ...	0	6	657	0
	Soft greenish-grey sandstone	1	5	658	5
	Greenish gritty clay	1	0	659	5
	Hard, greenish-grey, calcareous sandstone, fossiliferous	3	2	662	7
	Greenish-grey calcareous and gritty clay, shelly in places	1	4	663	11
	Greenish-grey sandy clay and gritty bed, shelly in places	1	2	665	1
	Greenish calcareous sandstone, with mass of shelly rock	1	5	666	6
	Greenish sand-rock and loose sand, with clay-seams, shelly in places	4	1	670	7
	Greenish gritty sand-rock and loose sand ...	1	2	671	9
	Dark grey, laminated clay, shelly in places...	7	0	678	9
Dark grey, laminated clay, shelly in places, with nodules of iron pyrites.....	5	4	6		
Grey gritty rock and loose sand	0	10	684	11	
Cornbrash.	Hard grey shelly limestone and dense grey and somewhat gritty limestone, with layer of sandy marl (4 inches) 8 feet from base, and layer of dull grey clay, with shells, at depth of 702 feet	18	3	703	2
	Clay, with a trace of fossils; marly oolitic bed with ochreous galls at depth of 705 feet, and hard greenish-grey marl at 708 and 709 feet	8	4	711	6
'Forest-marble (base not reached).	Clay.....	4	0 $\frac{1}{2}$	715	6 $\frac{1}{2}$
	Grey shelly oolitic limestone	1	3 $\frac{1}{2}$	716	10
	Grey marl	2	1	718	11
	Grey shelly oolitic limestone	2	8	721	7
	Hard marl, with band of shelly limestone; fragments of lignite	2	4	723	11
	Clay.....	4	10	728	9
	Pale grey earthy and shelly limestones	2	0	730	9
	Grey shelly marl	0	3	731	0
The boring was ultimately (December 23rd, 1884) carried to a depth of				736	2

2. NOTES on the FOSSILS obtained from the WELL-SINKING at SWINDON
By E. T. NEWTON, Esq., F.G.S.

KIMERIDGE CLAY.

From 8 feet to 72 feet, Kimeridge Clay was passed through, but only a few fossils were collected: thus between 10 feet and 16 feet *Rhynchonella inconstans*, Sby., *Ammonites cordatus*, Sby., and *Ostrea deltoidea*, Sby., were noticed; at 45 feet *Astarte* and *Thracia depressa*, Sby., and from 45 feet to 52 feet *Belemnites* were met with.

The earthy Limestone-bed with iron-shot grains, between 50 feet and 50½ feet, yielded:—

Pecten lens?, Sby.
Perna, sp.
Ostrea deltoidea, Sby.
Astarte, sp.
Myacites recurvus, Phil.
—, sp.

Pholadomya protei?, Ag.
Ammonites cordatus, Sby., var. *excavatus*, Sby. (= *A. serratus*, Sby.).
— *rotundus*, Sby.
— *varicosatus*, Buckl.

CORAL RAG.

The series of alternating beds, from 72 feet to 112 feet, probably represent the "Coral Rag," but no determinable fossils were obtained from them, although there are indications of shells and possibly Echinoderm spines.

OXFORD CLAY.

The beds from 112 feet to 685 feet are, no doubt, correctly referred to the Oxford Clay; but the occurrence in the lower parts of *Ammonites Koenigi*, and of an Ammonite which cannot be distinguished from some forms of *Am. calloviensis*, would seem to indicate that these lower beds may be the equivalents of the Kellaways Rock. For convenience of comparison, the fossils have been divided into groups corresponding to changes in the nature of the strata.

From 112 feet to 400 feet, chiefly clay:—

Gryphæa dilatata, Sby.
Pecten, sp.
Pinna mitis, Phil.
Arca, sp.
Goniomya v-scripta, Sby.
Myacites recurvus, Phil.
Nucula ornata, Quenst.

Pholadomya, sp.
Trigonia irregularis, Seeb.
Alaria trifida, Phil.
Ammonites cordatus, Sby.
— —, var. *excavatus*, Sby. (= *A. serratus*, Sby.).
— *perarmatus*, Sby.

From 400 feet to 622 feet, chiefly clay, with bands of *Septaria*:—

Anabacia orbulites, Lamx.
Serpula vertebralis, Sby.
Avicula inæquivalvis, Sby.
—, sp.
Gryphæa dilatata, Sby.
— *bilobata*, Sby.
Inoceramus.
Pecten, sp.
Pinna mitis, Phil.
Ostrea, sp.

Arca Quenstedti, Lycett.
—, sp.
Astarte carinata, Phil.
— *ovata*, Smith.
Cardium, sp.
Corbula, sp.
Goniomya v-scripta, Sby.
Modiola, sp.
Nucula ornata, Quenst
Pholadomya, sp.

Thracia depressa, <i>Sby.</i>	Ammonites cordatus, var. excavatus, <i>Sby.</i>
Unicardium, sp.	— crenatus, <i>Brug.</i>
Actæon retusus, <i>Phil.</i>	— Duncani, <i>Sby.</i>
Alaria trifida, <i>Phil.</i>	— hecticus, <i>d'Orb.</i>
Cerithium muricatum, <i>Sby.</i>	— Jason, <i>Rein.</i>
Pleurotomaria reticulata, <i>Sby.</i>	— —, var. Gulielmi, <i>Sby.</i>
Ammonites Bakeriæ, <i>d'Orb.</i>	— —, var.
— —, var. fluctuosus, <i>Pratt.</i>	— Kœnigi, <i>Sby.</i>
— Brightii, <i>Pratt.</i>	— Lamberti, <i>Sby.</i>
— cordatus, <i>Sby.</i>	

434 feet to 622 feet contained:—

Ammonites macrocephalus, <i>Schloth.</i>	Acanthoteuthis antiquus, <i>Pearce.</i>
— Mariæ, <i>d'Orb.</i>	Belemnites abbreviatus?, <i>Miller.</i>
— modiolaris, <i>Luid.</i>	— Owenii, <i>Pratt.</i>
— perarmatus, <i>Sby.</i>	— sulcatus, <i>Miller.</i>
— plicatilis, <i>d'Orb.</i>	Nautilus hexagonus, <i>Sow.</i>

From the Septaria found at 623 feet, the following fossils were obtained:—

Wood.	Ammonites calloviensis, <i>Sby.</i>
Rhynchonella, sp.	— Jason, <i>Rein.</i> , var.
Cerithium, sp.	— modiolaris, <i>Luid.</i>

From 624 feet to 640 feet, laminated shelly clay with occasional beds of sandy clay:—

Wood.	Myacites recurvus, <i>Phil.</i>
Avicula inæquivalvis, <i>Sby.</i>	Pholadomya acuticosta, <i>Sby.</i>
Gryphæa dilatata, <i>Sby.</i>	— parvicosta, <i>Ag.</i>
—, sp.	Trigonia irregularis?, <i>Seeb.</i>
Pecten, sp.	Alaria trifida, <i>Phil.</i>
Pinna mitis, <i>Phil.</i>	Ammonites calloviensis, <i>Sby.</i>
Arca, sp.	— Gowerianus, <i>Sby.</i>
Astarte carinata, <i>Phil.</i>	— Jason, <i>Rein.</i> , var. Gulielmi, <i>Sby.</i>
Modiola, sp.	Belemnites Owenii, <i>Pratt.</i>

From 641 feet to 684 feet, alternating clays, sands, and sandstones:—

Serpula tetragona, <i>Sby.</i>	Pholadomya acuticosta, <i>Sby.</i>
Avicula ovalis, <i>Phil.</i>	— parvicosta?, <i>Ag.</i>
— inæquivalvis, <i>Sby.</i>	Thracia depressa, <i>Sby.</i>
Gryphæa dilatata?, <i>Sby.</i>	Trigonia irregularis, <i>Seeb.</i>
—, sp.	Cerithium muricatum, <i>Sby.</i> , var.
Pecten, sp.	— Damonis, <i>Lycett.</i>
Perna mytiloides, <i>Ziet.</i>	Ammonites Bakeriæ, <i>d'Orb.</i>
Plicatula?	— cordatus, <i>Sby.</i> , var. excavatus, <i>Sby.</i> (= <i>A. serratus</i> , <i>Sby.</i>)
Arca Quenstedti, <i>Lycett.</i>	— Jason, <i>Rein.</i>
Astarte carinata, <i>Phil.</i>	— Kœnigi, <i>Sby.</i>
Isocardia tenera, <i>Sby.</i>	— modiolaris, <i>Luid.</i>
Leda Phillipsii, <i>Morris.</i>	— Gowerianus, <i>Sby.</i>
Modiola bipartita, <i>Sby.</i>	Belemnites Owenii, <i>Pratt.</i>
Myacites recurvus, <i>Phil.</i>	

CORNBRASH.

The fossils named in the list below were obtained from depths between 685 feet and 703 feet. Some of them were from the

marly beds, but the exact position of the greater number is uncertain:—

Cristellaria crepidula, *F. & M.*
 — *cultrata*, *Montf.*
 — *rotulata*, *Lam.*
Lituola nautiloidea, *Lam.*, var.
depressa?, *Jones.*
Serpula tetragona, *Sby.*
Cytheridea subperforata?, *Jones.*
Echinobrissus clunicularis, *Luid.*
Rhynchonella varians, *Schloth.*
Waldheimia obovata, *Sby.*
 — *ornithocephala*, *Sby.*
Avicula echinata, *Sby.*
Lima, sp.

Ostrea, sp.
Pecten demissus, *Phil.*
Gresslya peregrina, *Phil.*
Modiola Sowerbyana, *d'Orb.*
 —, sp.
Myacites decurtatus, *Phil.*
 — *securiformis*, *Phil.*
 — *sinister*, *Ag.*
 — *Terquemeus*, *Buv.*
Trigonia, sp. (costate form).
 —, sp. (clavellate form).
Cylindrites?
Natica, sp.

FOREST-MARBLE.

The beds from 703 feet to 736 feet, the lowest depth at present reached, are regarded as Forest-marble. The fossils were chiefly obtained from the lowest part, about 730 feet, and in the thin clay partings of the harder shelly rock.

Wood.
Serpula tricarinata, *Sby.*
 — *tetragona*, *Sby.*
 —, sp.
Cidaris, spine.
Acrosalenia, spines and plates.
Pentacrinus scalaris, *Goldf.*
Diastopora diluviana, *Lamx.*
Entalophora (*Spiropora*) *straminea*,
Phil.
 —, sp.
Terebellaria ramosissima, *Lamx.*
Rhynchonella concinna, *Sby.*
Waldheimia digona, *Sby.*

Waldheimia obovata, *Sby.*
Terebratula coarctata, *Park.*
Avicula, sp.
Ostrea gregaria, *Sby.*
 — (*Exogyra*) *lingulata*, ? *L. & M.*
 — *Sowerbyi*, *L. & M.*
Pecten vagans, *Sby.*
 — *lens*, *Sby.*
Lima duplicata, *Sby.*
Arca, sp.
Modiola imbricata?, *Sby.*
Cerithium, sp.
Gasteropods (minute).

E. T. N.

3. Few fossils have been obtained from the Kimeridge Clay, but they include one Ammonite (*A. cordatus*), an Oxfordian form, which is known, however, from the Lower Kimeridge Clay of Yorkshire.

Towards the base of what is now included in the Kimeridge Clay at Swindon there is a bed of iron-shot earthy limestone, six inches in thickness, which has yielded *Ammonites cordatus*, var. *excavatus* (regarded as the *Ammonites serratus* of Sowerby), and this is a well-known Lower Kimeridge fossil, though found also in the Oxford Clay. *A. rotundus* likewise occurs, and this is a Kimeridge form*. *Ostrea deltoidea* occurs, and this species is abundant in the upper Corallian beds in many localities.

This fossiliferous bed reminded me of the gritty limestone of Ringstead Bay, near Weymouth, termed the "Kimeridge Grit" by

* See J. F. Blake, *Quart. Journ. Geol. Soc.* vol. xxxi. pp. 211, 215, &c.

Mr. R. Damon, which has yielded a considerable number of fossils*. That layer, however, is regarded as the top of the Corallian beds by Messrs. Blake and Hudleston, and should no doubt be placed on that horizon. The fossils found in the Swindon bed are not sufficient to enable any palæontological comparison to be made; but when we compare the Swindon section with that at Highworth, about six miles to the north-east, we might be disposed to put more than we have included with the Corallian rocks at Swindon.

The general section at Highworth has been represented as follows by Messrs. Blake and Hudleston†:—

	ft.	in.
Coral Rag.....	1	0
Oolitic Flags and Sandy Clay	11	0
Shell-bearing gritty beds (Main Limestone)	12	0
Hard Band	2	0
Loose Calcareous Sands	14	0
Clay? and Sands in alternations	70?	0
	<hr/>	
	110	0

It is therefore quite possible that the iron-shot limestone at Swindon may represent the "Coral Rag" in the above section, and the clays beneath may represent the "Oolitic Flags and Sandy Clay."

During the early portion of the well-sinking at Swindon very many specimens were not preserved. Moreover, from the main mass of the Corallian series no determinable fossils were collected. But the character of the record suggests that the lower beds at Swindon are not so thick as Messrs. Blake and Hudleston represent them to be at Highworth, although their estimate, of a total thickness of 110 feet, includes 70 feet of clay and sand, which they insert with doubt.

At the same time, throughout the south-west of England (to confine my remarks to the area with which I am acquainted) the Kimeridge and Corallian beds are so intimately linked together, both lithologically and palæontologically, that we cannot fix a boundary between the formations which can be traced with precision. Nor need we be at all concerned at our failure; for nature could not be expected to fix rigid limits either for the accumulation of sedimentary strata or for the entombing of organic remains. Since writing the above remarks, I find that Mr. Hudleston has observed that "the name Corallian must be deemed a mere matter of convenience, not representing a formation in time"‡.

The Oxford Clay, as before mentioned, is 572 feet in thickness. Many fossils have been obtained, and these are grouped together as coming between certain depths, although we have no reason to draw definite lines. Broadly speaking, however, the record furnishes evidence of the Callovian fauna at the base, and of the incoming in succession of the "*ornatus*" and "*cordatus*" types of Ammonites. And it is satisfactory to find the ordinary succession of Ammonite-

* See 'Geology of Weymouth,' &c. New edition, 1884, p. 65.

† Quart. Journ. Geol. Soc. vol. xxxiii. p. 272, and Table, p. 404.

‡ Proc. Geol. Assoc. vol. v. p. 409.

forms maintained, even if the species are not limited to the often rigid and therefore unnatural definitions of a zone.

Thus in the upper 288 feet, *Ammonites cordatus* and *A. cordatus* var. *excavatus* are met with. This division would therefore correspond with the "cordatus-clays," although the two *Ammonites* occur a little lower down together with other species.

In the next 220 feet, *A. crenatus*, *A. Duncani*, *A. Jason*, *A. Koenigi*, *A. Lamberti*, *A. Mariae*, and *A. plicatilis* occur. And this division no doubt represents the "ornatus-clays" of the Lower Oxfordian. In the next 18 feet we find *A. Jason*, var. *Gulielmi*, and *A. calloviensis*. The lowest 44 feet, comprising alternations of clays, sands, and sandstones, yielded *A. Koenigi*, *A. Bakeriae*, and *A. modiolaris*, found also higher up; likewise *A. Gowerianus*. The last-named two species are usually regarded as Callovian forms.

Gryphæa dilatata occurs over 500 feet down in the Oxford Clay. This fossil is especially common in the upper part of the formation, in brickyards near the junction with the Corallian rocks in the south-west of England. A small form, difficult to distinguish from *G. bilobata*, however, occurs lower down, even in the Kellaways Rock.

The development of sandy beds at the base of the Oxford Clay is interesting. On lithological evidence, about 44 feet may be assigned to the Kellaways Rock; but if we consider *Ammonites calloviensis* to belong exclusively to this rock, then at least 18 feet more may be grouped with the Kellaways division. The evidence, however, agrees with that furnished in other localities, that the Kellaways Rock is but an irregular and impersistent sandy basement-bed of the Oxford Clay, locally fossiliferous.

So far as I am aware, no good sections of Kellaways Rock are now to be seen near the village of Kellaways. The beds, consisting of fossiliferous and somewhat flaggy calcareous sandstone, are exposed beneath the Alluvium of the Avon, about half a mile below Kellaways Bridge; and both here and at Christian Malford, where the rock has also been observed, this fossiliferous horizon is probably some distance above the base of the Oxford Clay. At the latter locality the section was described by Lonsdale as follows:—

Clay.	ft.	in.
Rotten rubbly stone with few organic remains	5	0
Sandstone, abounding with fossils	3	0
Sand	4	0
Clay.		

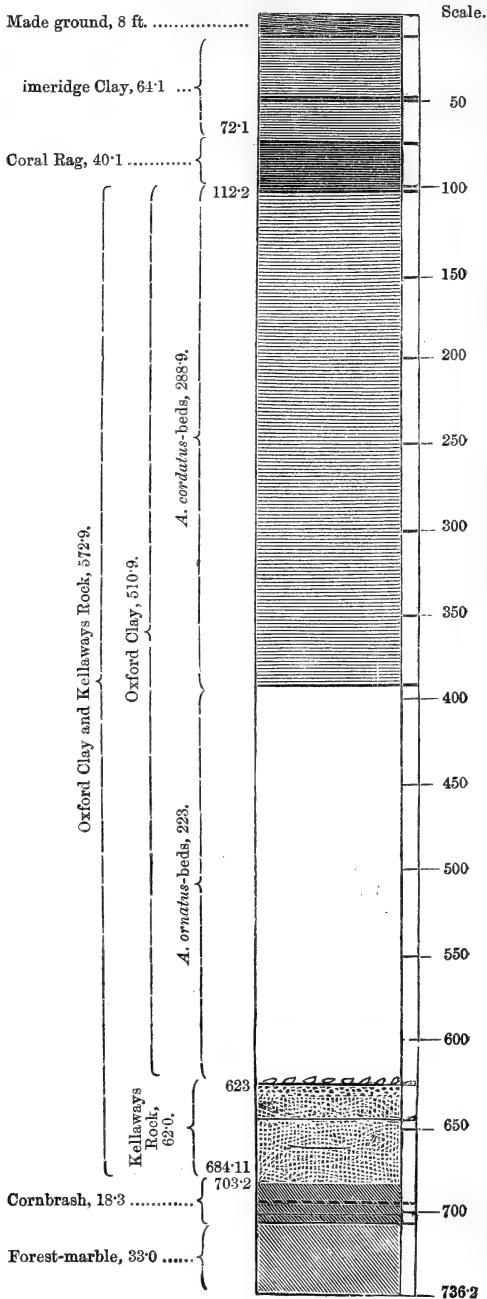
The rock at Kellaways attracted the attention of William Smith, on account of the numerous organic remains in it, for the fossils are sometimes so numerous as to constitute nearly the whole of the stratum; but, as Lonsdale has remarked, they are often wanting*.

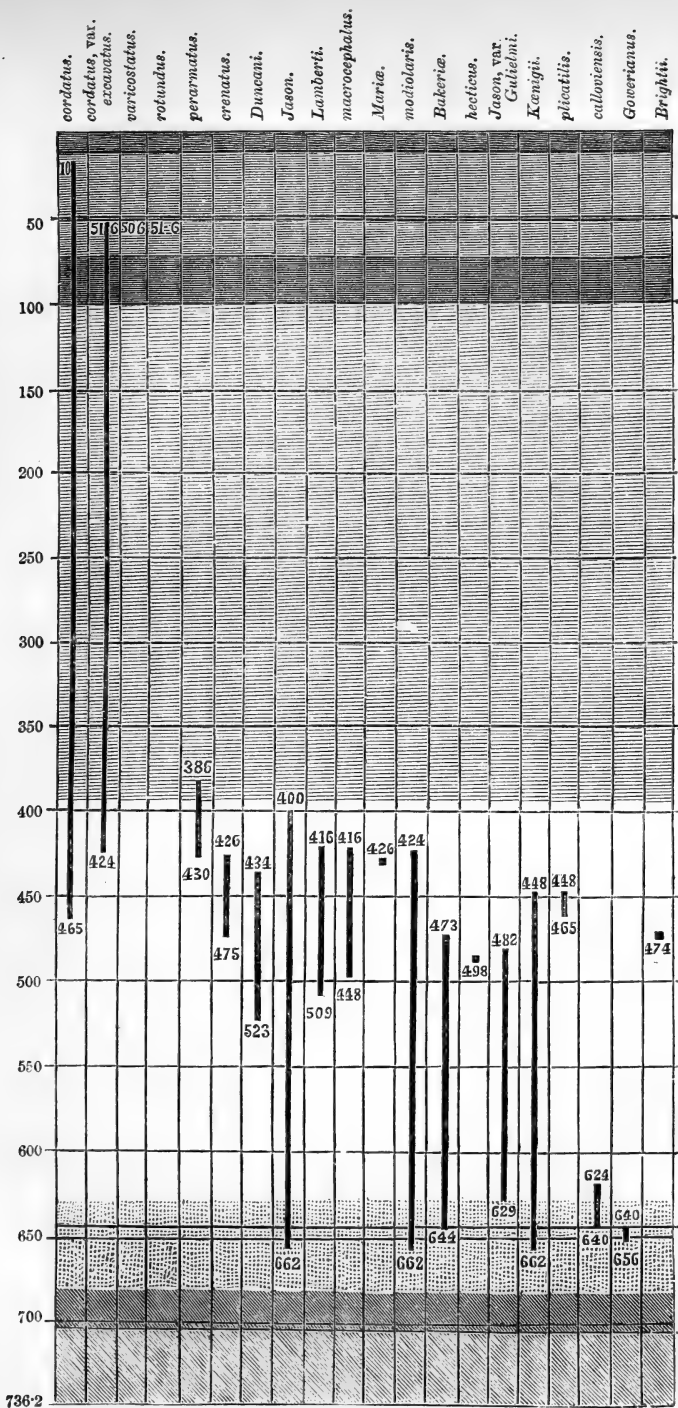
Near Trowbridge bands of sandstone are occasionally to be seen in brickyards opened in the lower beds of the Oxford Clay †.

* Trans. Geol. Soc. ser. 2, vol. iii. p. 261.

† See R. N. Mantell, Quart. Journ. Geol. Soc. vol. vi. p. 312.

Vertical Diagram-section of the Swindon Well-sinking, with Table of the Vertical Range of Species of Ammonites.





736.2

Sections, however, are very rare, so that but little can be said about the southern range of the Kellaways Rock. The lowest parts of the clay are perhaps too sandy for brick-making, and the ground is as a rule too low to have been opened up in railway-cuttings.

South of Cirencester, Prof. Hull observes that at the base of the Oxford Clay "there occurs a thin series of yellowish sands and calcareous sandstone, highly fossiliferous, many of the fossils being those of the Oxford Clay"*. Traces of the Kellaways Rock also occur near Malmesbury.

Further north the variable thickness and mineral character of the "Kellaways Sands, Sandstones, and Clays," in their extension from Wiltshire to Yorkshire, have been remarked on by Prof. Judd † and Mr. Hudleston‡.

The Cornbrash and the Forest-marble call for no particular remarks; many of the characteristic fossils occur, and in the latter formation we find *Terebratula coarctata*, which is suggestive of the Bradford-Clay zone.

4. We now come to the Saline Waters at Swindon, and to the question of their source.

The water from the Corallian beds, analyzed by Mr. F. W. Harris, showed 144·2 grains of solid matter in the imperial gallon; this included 86 grains of sodium chloride, and 49 grains of sodium carbonate. The water from the Forest-marble, also analyzed by Mr. Harris, showed 2131·85 grains in the imperial gallon, and this comprised 1824 grains of sodium chloride, 191 grains of calcium chloride, 88 grains of magnesium chloride, &c. The amount of saline matter was therefore nearly 15 times greater than in the upper waters. No sodium carbonate was detected in the lower springs, and these, as remarked by Mr. Harris, present some similarity to ordinary sea-water. Thus the amount of sodium chloride was almost identical (1824 grains at Swindon, and 1964 grains in sea-water), and so also with potassium chloride (16 grains at Swindon, 15 grains in sea-water). On the other hand calcium chloride, of which 191 grains occur in the Swindon water, is not noticed in sea-water; while the latter contains a much larger proportion of magnesium chloride, and also considerable quantities of magnesium sulphate and calcium sulphate, represented only by 1 grain of calcium sulphate in the Swindon water. With this exception the absence of sulphates from the Swindon water is noteworthy.

The following analyses show the number of grains per imperial gallon §:—

* Geology of parts of Wilts and Gloucestershire (Mem. Geol. Survey), p. 19.

† Geology of Rutland, &c. (Mem. Geol. Survey), p. 232.

‡ Proc. Geol. Assoc. vol. iv. p. 410.

§ Some of these analyses were published by Prof. Prestwich in a paper read before the Ashmolean Society, 1876. See also C. E. De Rance, Trans. Manchester Geol. Soc., Dec. 1884.

	G. W. R. Swindon.	Purton Spring, A. Voelcker.	Purton Spring, H. M. Noad.	Oxford, St. Clement's.	Marston, Cheshire, Brine.	English Channel, Sea-water.
Sodium chloride	1824·37	34·29	...	748·30	17655·40	1964·16
Sodium carbonate ...	.....	...	...	.....	25·20	.....
Sodium sulphate .....	.....	112·23	174·90	357·63	102·20	.....
Potassium sulphate ...	.....	1·91	10·26	.....	trace	.....
Potassium chloride ...	16·56	...	...	.....	.....	15·31
Potassium carbonate .	.....	28·88	...	.....	.....	.....
Calcium chloride.....	191·11	...	...	.....	.....	.....
Calcium sulphate.....	1·25	83·87	62·56	135·37	273·20	98·46
Calcium carbonate ...	.....	...	40·60	7·63	trace	2·31
Calcium phosphate ...	.....	...	...	.....	trace	.....
Magnesium chloride .	88·47	...	30·00	27·30	.....	256·66
Magnesium carbonate	8·71	...	2·10	.....	74·90	.....
Magnesium sulphate .	.....	77·20	76·59	.....	.....	160·70
Magnesium bromide .	.....	0·92	...	.....	.....	2·05
Sodium bromide .....	.....	...	...	.....	7·70	.....
Sodium iodide .....	.....	0·66	0·88	} trace	trace	Iodine traces
Silica	}	1·28	2·08	1·26	.....	.....
Ferric oxide	} 0·39	} 0·28	...	trace	trace	.....
Alumina .....	} .....	} .....	...	.....	trace	.....
Ammonia	0·99	...	...	.....	.....	traces
Ferrous carbonate ...	*	...	...	.....	.....	.....
Manganous carbonate	.....	...	...	.....	trace	.....
Organic Matter, &c. .	.....	8·75	1·14	0·10	.....	.....
	2131·85	350·27	401·11	1277·59	18138·60	2499·65

The occurrence of saline waters in the vicinity of Swindon is, however, not new. In an old topographical work it is mentioned that "almost all the well-waters about the north part of Wiltshire are very brackish . . . At Cricklade their water is so very salt that the whole town are obliged to have recourse to a river hard by for their necessary uses." And it is stated that the waters at Highworth, Wootton Bassett, Poulshot, and Lavington near Devizes are saline †. Apart, however, from the interesting and more or less valuable records published in the "good old times," when mineral springs were discovered nearly all over the country, there are more modern records of saline waters in the neighbourhood of Swindon. And it will perhaps be desirable to consider these records in topographical order.

In a well sunk near Rodbourne Lane, north-west of Swindon, in

* In the water of the Swindon well, ferrous carbonate, bromides, boric acid, and free carbonic acid are noted by Mr. Harris, but their quantities were not estimated.

† John Aubrey, Nat. Hist. of Wiltshire (1691). Edit. by J. Britton, 1847, pp. 21, 25.

1858, an alkaline mineral water was found. The strata passed through were as follows :—

	feet.
Kimeridge Clay	68
Corallian Beds	27
Oxford Clay	36
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/>
	131

In 1859 and 1860 the well was bored to a further depth of 367 feet (total 498 feet), presumably in Oxford Clay. The water obtained from the Corallian beds was analyzed by Mr. W. H. Stanier with the following results :—

	Grains per imperial gallon.
Sodium carbonate	45·0
Sodium chloride	56·0
Calcium and magnesium sulphate ..	4·4
Silica, alumina, &c.	1·4
Organic matter, &c.	5·2
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/>
	112·0

This water is very similar to that obtained from the Corallian beds in the new well-sinking at Swindon.

In 1862 analyses were published by Dr. H. M. Noad and Dr. A. Voelcker of a saline spring at a place known as Salt's Hole, between Purton and Cricklade. This locality is on the Oxford Clay, although very likely the water issued from the Corallian beds in the neighbourhood. The analyses showed between 350 and 400 grains of saline matter in the gallon, consisting principally of sodium sulphate, together with calcium and magnesium sulphates. Unfortunately the doctors disagreed in the arrangement of their results—in the one case 34 grains of sodium chloride were identified and no magnesium chloride; and in the other case 30 grains of magnesium chloride were included and no sodium chloride. The amount of saline ingredients differed in the two analyses as much as 50 grains; and Dr. Voelcker observed, "Probably the composition of the saline residue varies at different seasons, and the water, like other saline waters obtained only in limited quantities, is not always of the same composition"* . The yield of water was about 120 gallons per day.

At Melksham, also, mineral springs have been met with. The first discovery was made many years ago in sinking a shaft in search of coal. "After penetrating to a great depth the miners came to a very hard rock [probably Cornbrash, and perhaps also Kellaways Rock], on piercing through which this water rushed in upon them, and was so abundant that the scheme for finding coal was entirely abandoned. . . . The spring ever since continued to flow

* See *Quart. Journ. Chem. Soc.* vol. xiv. pp. 43-46.

[or rather to ooze out] above the original level of the field." The water on examination was found to contain 552 grains of saline matter in a gallon, and this seems to have been chiefly sodium chloride, together with magnesium and calcium chlorides, calcium sulphate, magnesium and calcium carbonates, and ferric oxide.

In 1815 "the Melksham Spa Company" was formed, and in order to procure an abundant supply of saline water, another well was sunk in a field to the east of the old saline spring. The record of this well has been published, and from the account of the strata there can be no doubt that the Oxford Clay and Kellaways Rock were passed through, as well as the Cornbrash, and that the waters, as at Swindon, welled up from the Forest-marble. It may therefore be interesting to quote the full account of this well-sinking.

After having dug one hundred feet they commenced the process of boring, under the superintendence of Mr. Brough, an able engineer, who after twelve months' labour, on the 1st of March, 1816, obtained the much-desired object. Since that date one hundred feet more were sunk.

The following are the particulars of the various strata, in the words of the engineers :—

- | | |
|-------------------|--|
| [OXFORD CLAY.] | <p>" A series of marl, dark-coloured, ninety feet thick, which in the digging broke into rhomboids.</p> <p>" Then marl again, about one hundred and thirty-two feet thick, varying in colour ; most of this presented in every fracture or section which could possibly be made, a glut of the remains of marine organized bodies, among which were many of the <i>Cornu Ammonis</i>, most beautifully gilt with the pyrites of iron, assuming every metallic lustre imaginable. The <i>Nautilus</i> also often occurred. The specific gravity of this mass was considerably greater than that of the foregoing, owing to its containing much iron. Towards the bottom of this marl thin irregular beds of jet were met with ; also, some large turtle-formed stones, which were extremely hard. [Septaria.]</p> <p>" Next a layer of stone two feet thick, in hardness equal to granite.</p> <p>" Marl again, in thickness fifty feet, colour as above.</p> |
| [KELLAWAYS ROCK.] | <p>" Afterwards stone, two feet six inches thick, moderately hard, but differing from any of the foregoing, being more granulated, and, when tried between the teeth, exceedingly gritty.</p> <p>" Then marl, in thickness eighteen feet.</p> <p>" The character of this marl was also different from any of the above, being more indurated, as also gritty.</p> |
| [CORNBRASH.] | <p>" Next stone, in thickness twenty feet, moderately hard, and of a lighter colour than any preceding. This was divided into about eight strata, by thin beds of clay, from one inch to two and a half thick.</p> |
| [FOREST-MARBLE.] | <p>" Then alternate strata of stone and clay, united thickness twenty-three feet six inches ; the beds of clay from six to twelve inches.</p> <p>" Afterwards a bed of stone two feet six inches thick. This was whiter than any yet met with, and moderately hard.</p> <p>" Stone succeeded, eleven feet in thickness, very hard, and separated into about five or six strata, by beds of clay mixed with a little sand ; these beds were from one to four inches thick.</p> <p>" Total depth from the surface, three hundred and fifty-one feet six inches."</p> |

After the borer had penetrated the eleven feet of stone, &c., it entered a bed of sand, and the water "gushed forth, in quantity

sufficient for every purpose." From experiments made by Dr. Gibbes, this water was found to hold in solution "the same salts as the other well, and in still larger proportion" *.

At Holt, between Melksham and Trowbridge, saline waters were discovered towards the close of the 17th century in sinking a well. An account was published by H. Eyre†, who states that the water contained "mixed salts," in the proportion of 3 drachms, 1 scruple, and 19 grains in 1½ gallons of water; no particular analysis, however, was given. The details of the strata passed through were noted by the Rev. Mr. Lewis as follows:—

[KELLAWAYS
ROCK?] [OXFORD CLAY.] { "After they had passed the upper turf they came to a blue Clay, which held about 3 foot; then they met with a yellow, brittle Clay, very much like ochre, used by painters, about 2 foot in thickness; and next with a loam of a looser texture, which sparkled with a kind of talc, called by the naturalists Selenites, and was intermixed with yellow ochre. . . .
"Below this, at about 10 foot deep, they came to a bed of stones, of a large size, and very hard texture [Septaria] . . .
"Here the springs come in, and below this the Clay was darker coloured, and interlaid with small shells of the Oyster, Escallop and Muscle kind, and with a few Belemnites curiously shaped. Here they met with stones of a very close texture, which when washed seemed to be nothing but a mass of shells jumbled and embodied together" ‡.

In connection with this subject it is interesting to note that saline or brackish water was also met with in a well made at Trowbridge (March 11, 1870, not finished). The well was sunk 160 feet and bored 40 feet "into Lias." The water was found to contain the following ingredients:—

Total solid impurity (in parts per 100,000)	144.34
Chlorine	36.70

The following appears to be the only account of this well at present published:—

"In sinking the shaft a salt spring was tapped and afterwards stopped out, but we were informed that some water came in at about 20 feet from the surface. Our analysis, given at page 105, shows the water to be excessively hard, and to contain a considerable proportion of common salt (6 lbs. in 1000 gallons, 3 oz. in this volume of water being about the usual proportion in good potable water), besides a rather large proportion of organic elements" §.

No details of the strata are given. The well was probably commenced in the Cornbrash (if not Oxford Clay), and if carried into the Lias it shows a great diminution in thickness of the Lower Oolitic strata. It is very likely, however, that the term "Lias" was that used by the well-sinker, and the well was simply carried through the Forest-marble into the Great Oolite.

* The Melksham Guide, 1815. Britton and Brayley, 'Beauties of Wiltshire,' vol. iii. p. 221.

† A brief Account of the Holt Waters in Wiltshire. 12mo. 1731.

‡ Phil. Trans. vol. xxxv. p. 489 (1728).

§ Sixth Report of the Rivers Pollution Commission, pp. 104, 105.

Again at Road, between Trowbridge and Frome, a mineral water was discovered more than 100 years ago. An account of it was published by S. Williams, who stated that it contained "steel, sulphur, and natron," but no analysis was given*. The water was probably obtained from the Cornbrash or Forest-marble.

Important evidence of saline water is that furnished by an artesian well made in 1832 at St. Clement's Brewery, Oxford. Attention has been directed to this water by Prof. Prestwich. The well was carried to a depth of 420 feet, through Oxford Clay 265 feet, and Great Oolite, &c., below; but no detailed account of the strata has been preserved. Chloride of sodium was most abundant in this water, and sulphate of soda came next in quantity†. (See analysis, p. 299.)

The conclusions to be drawn from these records are that in certain localities, as at Melksham and Trowbridge, at Swindon, and at St. Clement's, Oxford, where the Great Oolite series has been reached, the prevalent salt is chloride of sodium; and that while saline water has been found at higher levels in the Corallian beds, the water obtained is less saline, and the prevalent salt is in several cases sulphate of soda.

The occurrence of the saline water is suggestive of the proximity of Triassic rocks, as remarked by Prof. Prestwich in connexion with the well at St. Clement's, Oxford. He points out that the Cheltenham waters, which contain much chloride of sodium, issue from the Lower Lias, "but as the upper beds of the New Red Sandstone crop out a few miles west of Cheltenham, and pass under the Lias, geologists have concluded that the wells traverse the Lias and reach the New Red, and that it is from those beds that the saline water comes." Prof. Prestwich concludes "that the water at St. Clement's has its origin in the New Red Sandstone, and not in the Oolitic or Liassic strata, as would otherwise, from the depth of the boring, be the natural inference. If the water were from the Oolitic strata we should expect to find it much purer, and its solid matter to consist chiefly of carbonate of lime; if from the Marlstone or Lias to be more ferruginous and calcareous."

Curiously enough the water of the new Swindon well has yielded no carbonate of lime, very little sulphate of lime, and very little ferruginous matter. Moreover the saline waters found in the district vary very considerably, so that if the mineral matter be originally derived from Triassic rocks, the water is diluted and modified by other waters with which it has come in contact in rising towards the surface.

Concerning the position of the Triassic rocks we may make a few remarks. The deep boring at Signett, south of Burford, in Oxfordshire, is about seventeen miles north of Swindon, and there the following strata were penetrated:—

* An Experimental History of Road Water in Wiltshire. 8vo. London, 1731.

† Ashmolean Soc. 1876.

	feet.
Oolites	148
Lias and Rhætic beds	608
Red Marls	291
Red Sandstone	137
Coal-measures	225
	1409

The thickness of the New Red beds, according to Prof. Hull, diminishes in a south-easterly direction from the Staffordshire area, and he inferred that the Lias would disappear below Oxford*. Mr. Topley, moreover, has shown that the attenuation of the Oolites corresponds with the dip, so as to bring the New Red rocks nearer to the surface in a south-easterly direction from the Cotteswold outcrop †.

On the borders of the Bristol Coal-field the thickness of the Secondary strata is much reduced, and the Lias and Rhætic beds in places overlap the New Red strata and rest on the older rocks. A short distance west of Bath the Coal-measures come to the surface overlain by the Keuper Marls of very little thickness. Further south, on the eastern end of the Mendip range, near Frome, the Red beds and Lias are overlapped by the Inferior Oolite, which then rests in places directly on the Carboniferous Limestone.

The Bristol and Somerset Coal-field is probably bounded on the east by an underground margin of Lower Carboniferous rocks, which would underlie the Lias and Oolites east of Bath; but the more easterly arrangement of the older rocks is a matter of uncertainty, for near Wotton Underedge the Red Marls repose on Silurian rocks.

In this northern area a mineral water was obtained from a well sunk from 40 to 50 feet deep in the Lias. The locality is Cherry-rock Farm, north-east of Wickwar, and an analysis was published by Mr. T. J. Herapath. The salts present were magnesium sulphate 129 grains in the imperial gallon, sodium sulphate 122, calcium sulphate 75, calcium carbonate 31, and sodium chloride 60. Mr. Herapath states that most of the springs in the neighbourhood, when sunk to a great depth, are inclined to be salt ‡. Here the New Red strata are comparatively thin, and rest in all probability on the Silurian rocks.

Again, the thermal springs at Bath and Clifton, which contain, among other ingredients, sodium chloride, and in the former case a large amount of calcium sulphate, rise from the Carboniferous rocks in a district where no rock-salt is known to exist in the New Red strata §.

Moreover at Twerton, near Bath, saline waters containing 112·8

* Quart. Journ. Geol. Soc. vol. xvi. pp. 63, 71; see also the Memoir on the Triassic and Permian Rocks of the Midland Counties.

† Quart. Journ. Geol. Soc. vol. xxx. p. 186.

‡ Quart. Journ. Chem. Soc. vol. ii. p. 200.

§ One may neglect the evidence of pseudomorphous crystals of rock-salt.

parts per 100,000 of sodium chloride were thrown out "by a spring in the Lower Lias," probably rising from the Coal-measures; and "at Braysdown Colliery [near Radstock], 500 yards in depth, a constant volume of water is met with, which Mr. Biggs found to contain 1008 grains of common salt per gallon (or 1440 grains per 100,000): the water appears to be derived from the Coal-measures, and it is very salt indeed"*. Other instances might be given to show that the presence of sodium chloride in the waters of wells at a distance inland is not dependent on the proximity of the saliferous New Red Rocks; but it will be sufficient to mention the waters at Moira, in the Leicestershire coal-field, the thermal saline water in the "killas" at Camborn, in Cornwall †, and a spring on the south-west side of Derwentwater, which issues from a bed of grit ("Arenig Grit") in the Skiddaw Slates ‡.

Of course some of the saline waters may derive their ingredients from saliferous New Red Rocks at a considerable distance; for, as Prof. Prestwich remarks, "Thermal springs in non-volcanic districts, such, for instance, as at Bath and Buxton, may generally be considered as natural artesian wells, where water, after descending through permeable strata to great depths, escapes through fissures in the overlying strata (the sides of faults or dislocations) to the surface. The temperature of such springs, above the mean of the surface, is necessarily proportionate to the depth reached by the descending water; and, as the Bath waters have a temperature of 120° Fahr., we may assume the depth from which they rise to be about 3500 feet"§. In this case the shales at the base of the Carboniferous Limestone may support the waters.

The saline ingredients may, as at Clifton and at other places, be largely derived from sea-water, or perhaps, as has been suggested, sea-water may have been stored up in the rocks during the vicissitudes or "ups and downs" of past geological periods.

The question before us, however, is, whence come the saline waters at Swindon? We have mentioned those found elsewhere in the neighbourhood, but before concluding it will be desirable to note very briefly the occurrence of fresh waters in the same area.

5. Good supplies of fresh water have been obtained in certain localities in North Wilts, as at Malmesbury and Chippenham. At Malmesbury springs of an artesian character rise in the Abbey meadows from the Forest-marble. These, it is true, contain 25 grains of solid matter in an imperial gallon; but the chief constituent is carbonate of lime, with small proportions of sulphate of lime, chloride of sodium, &c. ||

At Chippenham, at Mr. Brotherhood's well, the Cornbrash and

* Report Brit. Assoc. for 1875, p. 141. See also C. E. De Rance, "On the Occurrence of Brine in the Coal-measures," Trans. Manchester Geol. Soc., Dec. 1884; and J. M'Murtrie, Proc. Bath Nat. Hist. Club, vol. vi. p. 84.

† J. A. Phillips, 'A Treatise on Ore Deposits,' 1884, p. 121.

‡ J. C. Ward, 'Geology of Northern Part of Lake District,' p. 53.

§ Geology, Chemical and Physical, p. 166.

|| J. H. Taunton, 'Proc. Cotteswold Club,' vol. vi. p. 301.

Forest-marble were penetrated, and a good supply of water was obtained. The section was as follows :—

		ft.	in.
Cornbrash.	Brash	9	6
Forest-marble.	Hard Clay	4	10
	Blue Clay	43	7
	Rock	5	0
Great Oolite.	Blue Clay	3	0
	Rock (blue oolitic limestone) ...	33	9
		<hr/>	
		99	8

Water gushed in from the south side of the well at the rate of 8000 gallons an hour. This contained 28 grains of solid matter per gallon, consisting chiefly of carbonate of lime, with chloride of sodium, carbonate of magnesia, sulphate of lime, &c. Dr. H. Letheby, who made the analysis, stated that although a little hard, it was in all other respects a good and wholesome water*. The river-waters near Chippenham contain similar ingredients.

In reference to the Swindon well, one would be disposed to doubt that fresh water is likely to be met with in carrying the shaft at the station to a greater depth, although, judging from the waters at Malmesbury and Chippenham, there is no reason why good water should not be obtained in the neighbourhood.

The Lower Oolitic strata outcrop successively to the north-west of Swindon, and, so far as the surface-evidence is concerned, the following formations would be expected to occur in carrying this boring to a greater depth :—

	feet.
FOREST-MARBLE : clays and sandy shales, fissile shelly oolite and flaggy limestone	80-100
GREAT OOLITE : compact limestone, shelly oolites and marls	140
FULLER'S EARTH : clay with occasional beds of hard marl or limestone	70 (or more).
INFERIOR OOLITE : oolitic and shelly limestone and marl	80-100.

Water is likely to occur in the Great Oolite, upheld by the Fuller's Earth, which throws out so many springs on the Cotteswold Hills ; or, again, water would be expected in the Inferior Oolite or underlying sands upheld by the clays of the Lias. But it is possible that the water that rises from the bottom of the Swindon well may include the supply held up by the Fuller's Earth, if present.

6. In the case of the saline waters of Swindon, Melksham, &c., having regard to their local distribution, and to the occurrence of comparatively fresh water in neighbouring wells, there can be little question that they rise from a considerable depth, and that the supplies of water in the upper strata are rendered saline by the waters that come from below.

Several lines of fault running generally in a north-easterly direction between Frome and Swindon are marked on the Geological Survey

* From notes furnished by Mr. Bryan Wood, of Chippenham, to Mr. H. W. Bristow.

Map, and it is possible that some saline waters burst out along these lines of dislocation. One can understand the introduction of saline waters from below into the Great Oolite series, if the Lower Jurassic clays be absent; but their occurrence in the Corallian series, having regard to the intervening mass of Oxford Clay, is puzzling.

The conclusion that suggests itself is, that the saline waters issue from Palæozoic strata, against a ridge of which the Lower Secondary strata abut in more or less attenuated form. This underground ridge may be some miles to the south of Swindon.

Naturally the question arises, should not some more positive evidence of the proximity of older rocks be furnished to justify this suggestion? No indications of shore-conditions are revealed in the Oolitic strata. But I may call attention to the fact that in the neighbourhood of Frome, where the Secondary strata come very near to the Palæozoic rocks, no very marked changes are met with in the Lower Oolites. The Inferior Oolite, it is true, presents here and there conglomeratic beds, but its ordinary oolitic character is generally maintained. The Fuller's Earth, Forest-marble, Cornbrash, and Oxford Clay are all exposed within three miles of the eastern end of the Mendip Hills (formed of Old Red Sandstone and Lower Carboniferous rocks), and these Oolitic strata show no departure from their ordinary characters. There are here, as elsewhere, sandy beds in the Forest-marble (Hinton Sandstone of Wm. Smith) and sandy beds at the base of the Oxford Clay and in the Corallian series. But we have no positive evidence in this neighbourhood of marginal deposits above the Inferior Oolite; so that while the older rocks of the Mendips, &c., may have stood out as islands here and there, yielding conglomerates in the New Red, Rhætic, and Lias times, these ridges of land disappeared beneath the waters in Inferior-Oolite times, and were probably smothered up by the newer Oolitic strata, which in places may nevertheless have rested directly upon the older rocks. Perhaps the underground structure in the neighbourhood of Swindon may present similar features, and we have, at any rate, the evidence, between Bath and Chipping Sodbury and elsewhere, of inliers or islands of Carboniferous rocks appearing in the midst of the Lias.

DISCUSSION.

The PRESIDENT remarked on the important data recently obtained by members of the Geological Survey from deep wells, and on the interesting evidence of thickness and relations of strata thus obtained. He inquired whether the effect of continuous pumping had been tried in order to reduce the saline character of the water.

MR. DE RANCE remarked on the light thrown upon Oolitic rocks by Mr. H. B. Woodward's studies. The British Association Committee of Inquiry into Underground Waters had paid much attention to the porous formations. The present section threw some light on Prof. Hull's views as to the thinning of the Lower Triassic rocks in the centre of England. The speaker showed how various members

of the Trias disappeared from north to south. He also pointed out how the thickness assigned, from calculation, by the Geological Survey in a published section, to the Jurassic beds near Swindon precisely agreed with the facts now disclosed. From the ascertained composition of saline springs in various formations, he showed that the water at Swindon was much less salt than the brines of the Keuper marls, and less so than those of the Coal-measures. Mr. Mylne was making a boring about three miles' from Swindon, and the information thus obtained would be a useful addition to that in the present paper.

Mr. MYLNE said that the boring just referred to by Mr. De Rance was commenced at the bottom of a shaft in the Cretaceous beds, of the thickness of which he gave some details. The Portland Sand was wanting, and the Kimeridge Clay was not completely bored through.

Prof. MASKELYNE said that the country was well known to him, and that in several wells near Swindon saline water was found, and he instanced one case near Purton where traces of iodides had been met with. The abundance of gypsum in the Kimeridge and Oxford Clays explained the abundance of calcium sulphate. He believed the water in the part of the Swindon well where the Coral Rag was penetrated would be improved by pumping, and cited instances of good water having been procured from the Coral-Rag beds in the neighbourhood by sinking through the Kimeridge Clay. The head of the Thames is an instance of a beautiful spring derived from beds fed by the water percolating the upper part of the Great Oolite north of Cirencester and Tetbury.

Mr. H. B. WOODWARD, in reply, said that for many months pumping had been resorted to at Swindon without success in obtaining better water. After pumping had been discontinued, the water from the lower strata gradually rose to within about 25 feet of the surface.

24. On a MANDIBLE of MACHÆRODUS from the FOREST-BED. By JAMES BACKHOUSE, Esq., F.G.S. With an APPENDIX by R. LYDEKKER, Esq., B.A., F.G.S. (Read April 7, 1886.)

[PLATE X.]

ABOUT two months ago I obtained from the Forest-bed of Kessingland, Suffolk, a specimen which I take to be the right mandibular ramus of a species of *Machærodus* (Plate X.). As I believe that no example of the lower jaw of any species of this genus has been met with in this country, I venture to send the following description of it.

Length from posterior margin of condyle to upper edge of symphysis at insertion of second incisor 204 mm.

Vertical depth below premolar at shallowest part of ramus 38·25 mm.

Depth at middle of diastema 51 mm.

Depth at lowest point of symphysis 63·75. Originally the depth at this point has apparently been 70, if not 75 mm.

The diastema is large (41 mm.) and, like the portion of the ramus immediately beneath it, curved inwards; it presents a fossa of 6 or 7 mm., from the direct line between the canine and cheek-teeth, for the accommodation of the upper canine. The anterior foramen is large, and in a line parallel to the adjoining base of the ramus. The condyle is imperfect, the length of the remaining portion being 38·2 mm., and the vertical thickness 19·1 mm. The coronoid process has lost its upper third, the remaining portion being 25 mm. in height and 38 mm. in width at the base.

In regard to the teeth, the sectorial has an antero-posterior diameter of 32 mm.; it is much worn diagonally by the action of the corresponding upper tooth, and anteriorly overlaps the premolar. The premolar has an antero-posterior diameter of 22·25 mm.; it is split vertically, while the apex of its anterior cusp and the outer edge have been worn away. The total length of the upper surface of the two teeth is 51 mm. The canine is likewise partially worn away and has lost its upper portion, the length of the remaining portion being 25 mm., and the breadth 15 mm. The first incisor has well-marked cusps, but wants its upper portion; its width is 11 mm. The second has a width of 7 mm., and a depth (back to front) of 11 mm.

Appendix by R. LYDEKKER, Esq.

With the consent of Mr. Backhouse I append a short note, in the hope that it may more fully elucidate the affinity of his interesting specimen, which undoubtedly belongs to *Machærodus*. I may observe, first of all, that the *Machærodus* of Pikermi* and Eppelsheim†

* *M. leoninus*, Wagner.† *M. (F.) aphanistus*, Kaup.

was identified with the typical Val d'Arno *M. cultridens*, first by Kaup* and subsequently by Gaudry†, the identification having been made solely from the comparison of the upper canines from the Val d'Arno with those from Eppelsheim and Pikermi. Dr. Major‡ speaks of the Pikermi *Machærodus* (of which several jaws are known §) as being closely allied to *M. cultridens*, but does not enter into further details. Falconer|| regarded *M. latidens* as undistinguishable from *M. cultridens*. In the Cat. Foss. Mamm. Brit. Mus., I have followed Kaup and Gaudry's view, as I had at that time no specimens which led me to doubt its accuracy ¶. In the Pikermi and Eppelsheim form there are two elongated lower premolars, and the diastema of the male is comparatively large. So far as I can find out, no jaws of the typical Val d'Arno form are known; and since all the other mammals from those beds are distinct from the Pikermi and Eppelsheim species, there are *primâ facie* grounds for considering that the identification of the Pikermi *Machærodus* with *M. cultridens* is not fully certain. *Machærodus latidens* has been hitherto known only by detached canines and incisors, the upper canines being relatively broader than in *M. cultridens*. *M. meganthereon* is a much smaller form, distinguished by the absence of serrations on the upper incisors.

Mr. Backhouse's specimen, which has lost the innermost incisors, indicates a species about equal in size to the Pikermi *Machærodus*, and, from the large size of the concavity for the upper canine and the descending mandibular flange, apparently belonged to a male. There is only one premolar, which is of comparatively small size, and from the sharpness of the alveolar border in front of this tooth it is evident that $\overline{\text{pm. 3}}$ was never developed. Compared with the mandible of a male of the Pikermi *Machærodus***, the fossil differs not only in the absence of $\overline{\text{pm. 3}}$, but is absolutely shorter, and has a relatively shorter and deeper diastema and a wider and shallower concavity for the upper canine, while $\overline{\text{pm. 4}}$ is relatively shorter. These differences are shown by the following dimensions, the length of $\overline{\text{m. 1}}$ of the continental form being taken from the Eppelsheim specimen B.M. No. 49967 *a*.

	Pikermi.	Forest-bed.
Interval between canine and carnassial	0.098	0.069
Length of carnassial	0.031	0.032
Length of fourth premolar	0.027	0.0215

* 'Neues Jahrb.' 1859, pp. 270-271.

† 'Animaux Fossiles et Géologie de l'Attique,' pp. 105-109.

‡ Quart. Journ. Geol. Soc. vol. xli. p. 3 (1885).

§ See Cat. Foss. Mamm. Brit. Mus. pt. i. p. 43.

|| 'Palæontological Memoirs,' vol. ii. p. 459.

¶ The question of the long range in time of the species as thus extended was not taken into consideration.

** See Cat. Foss. Mamm. Brit. Mus. pt. i. p. 43, no. 49674 (misprinted 59674). In an immature female (No. 49674 *bis*) the diastema is shorter and the ramus shallower; a specimen from Eppelsheim (No. 49967 *a*) has a similar short diastema and no descending flange, and therefore probably also belongs to an adult female in which the ramus is much deeper.

These differences are sufficient to indicate the specific distinction of the fossil from the Pikermi and Eppelsheim *Machærodus*.

In the absence of pm. 3 the fossil agrees with many examples of the North-American *M. neogæus* *, but is distinguished by the smaller size of pm. 4.

Having now shown that the specimen under consideration is specifically distinct from the Pikermi *Machærodus*, it remains to consider whether it should be identified with the Val d'Arno *M. cultridens* (from which the Pikermi form would then be distinct) or with *M. latidens* (if this be really distinct). A fragment of the upper canine of a *Machærodus* has been described from the Forest-bed by Prof. Lankester †, which he was disposed to identify with *M. cultridens* rather than with *M. latidens*; and this provisional identification, coupled with the occurrence in the Forest-bed of Val d'Arno species like *Elephas meridionalis*, *Rhinoceros etruscus*, and *Equus Stenonis*, is in favour of regarding our specimen as belonging to *M. cultridens*. On the other hand, since the Forest-bed also contains later mammals, such as *Elephas antiquus* and *primigenius*, *Hyæna crocuta*, and *Sus scrofa*, there is no reason why the Pleistocene *M. latidens* should not also be found there.

As it appears to me to be at present impossible to say whether *M. latidens* should be regarded as a well-marked species or merely as a variety of *M. cultridens*, we must await the discovery of a jaw of the latter in the Val d'Arno before the specific determination of Mr. Backhouse's specimen can be definitely settled; but from the evidence of Prof. Lankester's specimen I am rather inclined to think that it may belong to *M. cultridens*; and in view of this contingency it will be advisable for the future to separate to separate from the latter species the Pikermi and Eppelsheim form, and to retain for it the name of *M. aphanistus* ‡. It is interesting to observe that the present Forest-bed jaw evidently belongs to a more specialized species than the latter, as is indicated by its shorter ramus and numerically reduced cheek-dentition.

EXPLANATION OF PLATE X.

Right ramus of the mandible of a very old male individual of a species of *Machærodus*, from the Forest-bed of Kessingland, Suffolk. Fig. 1 shows the external surface, and fig. 2, the anterior aspect, on a scale of $\frac{1}{4}$; *i.* 3, outer incisor; *c.* canine; *pm.* 4, premolar; *m.* 1, true molar (carnassial or sectorial).

DISCUSSION.

Prof. FLOWER said there was no doubt about the generic identification, but it was to be regretted that the upper jaw, with its characteristic huge canine, had not also been found.

* See Cat. Foss. Mamm. Brit. Mus. pt. i. p. 48.

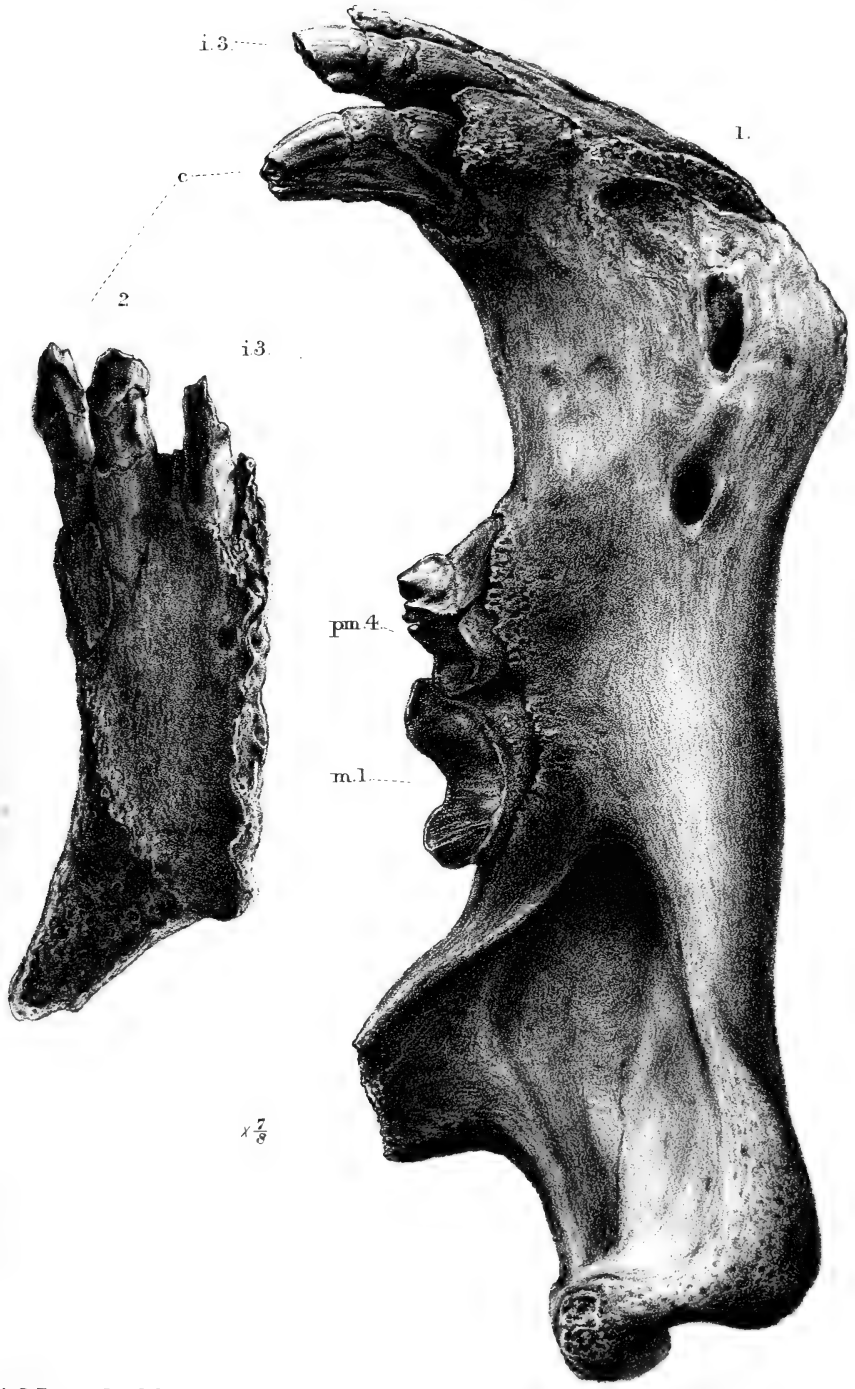
† Geol. Mag. 1869, dec. ii. vol. vi. p. 440, pl. vi.

‡ This name is thirty years earlier than *leoninus*, and (assuming the identity of the Pikermi and Eppelsheim forms) should therefore be adopted.

Mr. W. DAVIES had carefully compared the specimen with the fossils in the National Collection, and it approached most nearly to *M. leoninus* from Pikermi and *M. (Felis) aphanistus* from Eppelsheim, but differed from both. He pointed out the differences in detail.

Dr. WOODWARD called attention to the description by Prof. Ray Lankester, in the 'Geological Magazine' for 1869, of a canine of *Machærodus* from Cromer. Bones or teeth of this genus had also been found in Kent's Hole, at Creswell Crags, &c. The geographical distribution of the genus was remarkable. Mr. Backhouse was to be congratulated on this addition to our knowledge of the genus.

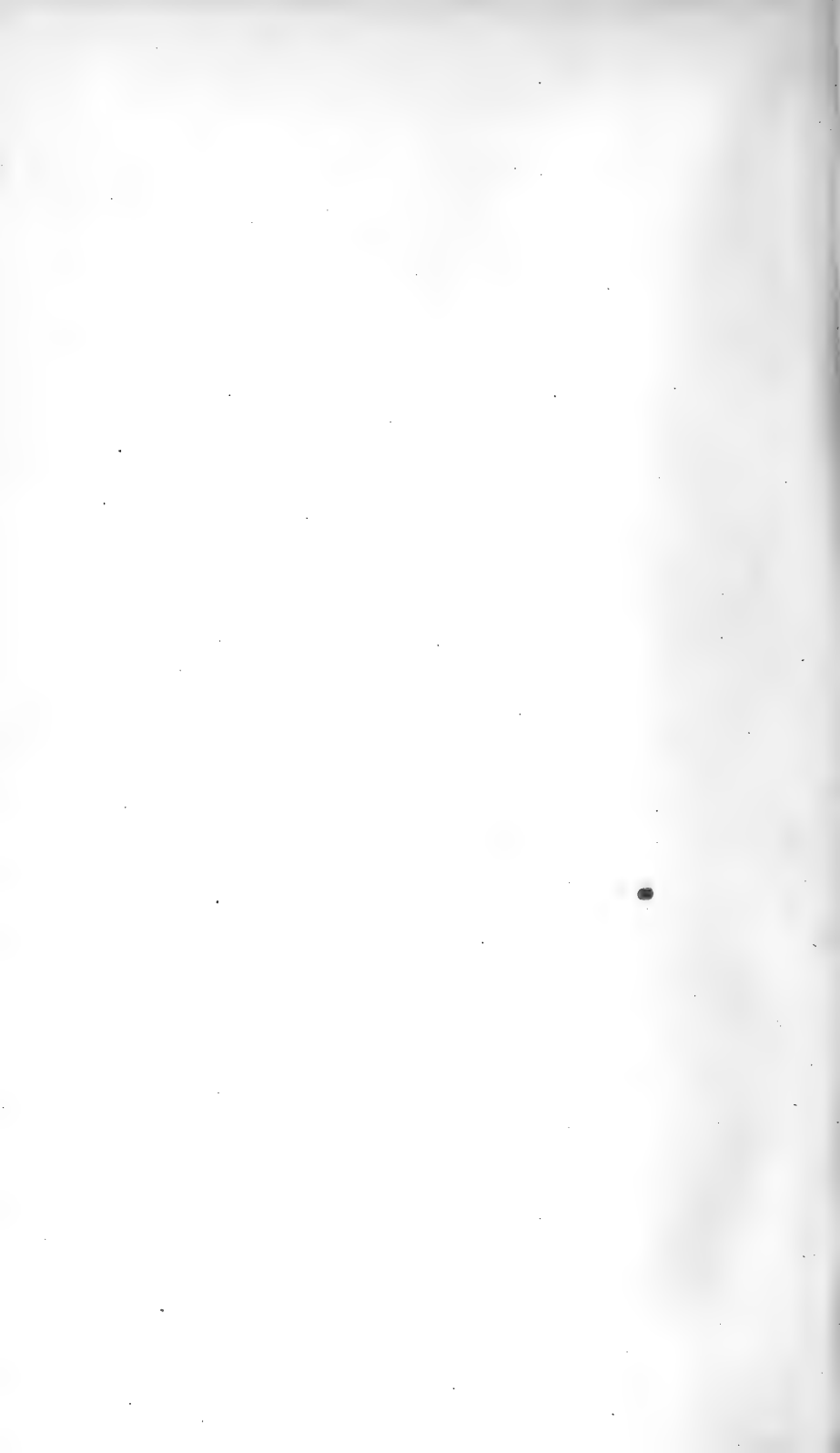
Mr. E. T. NEWTON had placed on the table the cast of the canine from Cromer, which had been considered by Prof. Ray Lankester nearest to *M. cultridens*. An incisor tooth had also been found in the Forest-bed and was exhibited. A portion of a humerus in the British Museum, and a fragment of a feline fibula in the Museum of Practical Geology, perhaps also belonged to this genus.



A. S. Ford del et lith.

Miscner Bros. imp.

MANDIBLE OF MACERODUS.



25. *On the EXISTENCE of a SUBMARINE TRIASSIC OUTLIER in the ENGLISH CHANNEL, off the LIZARD.* By R. N. WORTH, Esq., F.G.S. (Read May 12, 1886.)

It is with great pleasure that I am able to report to the Geological Society the existence of a submarine Triassic outlier in the English Channel, off the Lizard. The possibility of the presence of Triassic rocks in the Channel-area has been more than once suggested, and the occasional dredging of a fragment of sandstone has strengthened the hypothesis; no distinct evidence has, however, until now been procured.

A short time since Mr. Matthias Dunn, of Mevagissey, who is intimately acquainted with all the conditions of the Channel fishery, called my attention to the fact of the frequent occurrence of sandstone fragments in the bed of the Channel in a certain direction, and at my desire promised to supply me with a series of specimens. This he has now done, and the facts thus revealed are of a very remarkable character. All the examples were brought up entangled in the hooks of the fishermen's "long lines," which are laid along the sea-bottom for distances ranging even up to six miles. The positions from which the rocks come can therefore be ascertained with considerable precision; and each specimen or group of specimens was accompanied by its compass-bearing on some well-known point of the land, and the distance thence in miles. The bearings are magnetic and strictly correct; the distances are estimated, and therefore liable to a certain amount of error; though from constant practice and their knowledge of the peculiarities of the sea-bottom the fishermen are singularly accurate in these estimates.

The evidence that the rocks were *in situ* when entangled (partly by the marine growths upon them, and partly by their irregularities and the holes bored by *Pholades*) is clear. With two exceptions only, to be referred to hereafter, the specimens retained the characters of the original bedding. The upper surfaces of the fragments are, as a rule, bored; the lower are either free from marine organisms, or show only such minute ones as would grow on the under surface of a slab of rock that was gradually working loose from its parent reef. In all probability most of my specimens were detached from their places by the hooks that brought them to the surface.

The list of these rock specimens is as follows:—

1. Lizard, 10 miles N.W.—Fine-grained, soft, red Triassic sandstone, in layers $1\frac{1}{2}$ to 2 inches thick.

2. Lizard, 15 miles N.W.—Triassic sandstone of coarser grain, mottled red and grey.

3. Manacles Rocks, 16 miles N.W.—Fine-grained soft sandstone, grey, with a passing red tinge in places, in parts highly micaceous,

containing both black and white micas, the former rather segregative.

4. Falmouth Castle, 18 miles N.N.W.—Fine-grained, compact, red, jaspideous sandstone, much bored, possibly an altered rock. The specimen shows portions of two joint-faces, at right angles to each other, which have evidently been protected from the ravages of the *Pholades*.

5. Deadman, 25 miles N.E. by N.—This one spot supplied examples of four distinct Triassic rock-forms:—

a. Chocolate marl, spotted white. The edges of this nodule were rounded, but it could hardly be called rolled. From its softness this is very easily worn.

b. A "Potato Stone," partially coated with marl, and filled with pinkish calcite. The inside of the shell was studded with small brilliant pyramids of quartz. Five inches in longest external diameter.

c. Grey sandstone.

d. A nodule of Triassic trap, which may have been partially rolled, but was apparently in its form originally concretionary. It is a hard red rock of meagre feel, slightly micaceous, and very closely resembles some varieties of the Triassic trap of Thorverton, with affinities, so far as macroscopic observation goes, to those of Pocombe and Cawsand.

6. Deadman, 20 miles N. by E.—A light salmon-tinted drab calcareous sandstone, in a slab nearly two feet in longest diameter, the under surface intact and slightly pitted. This is the only example of the series that I am unable to match distinctly among the Red Rocks of Devon; but its associations here are apparently Triassic, and I therefore include it in my notes. Probably it may be identified by those more familiar with Triassic detail than myself; though, indeed, it may not be Triassic at all.

It will be seen that the affinities of this series are with the Keuper of Devon, and particularly with the rocks in the vicinity of Sidmouth.

A comparison of the bearings given will show that the rocks from which these specimens were derived lie to the S.E. of the Lizard promontory, occupying an area of which the centre may approximately be given, on the data to hand, as about 10 miles S.E. of the Lizard Head, and most of which lies beyond the 40-fathom line, and all beyond the 30-fathom. Of course with the information at present existing no attempt can be made to map out the boundary of this submarine Triassic outlier; but there is some evidence that it does not extend to the eastward, approximately, beyond the meridian of the Nare Head, in the fact that rocks brought up from the following positions do not include any of Triassic character:—Deadman, 3 miles N.W.; Deadman, 4 miles E.; Deadman, N.E. 10 and 12 miles; Deadman, 27 miles N. by W.; while the position which yielded the calcareous sandstone (No. 6) has produced pebbles of granitic, granitoid, and quartzite rocks, with flints, with no distinct example of Trias. So far as Falmouth Bay is concerned, we have

the evidence also of the occurrence of ochreous ash 10 miles S.W. of Falmouth itself.

I do not think it advisable to attempt more precise localization ; but there can be little doubt that this submarine Triassic patch is considerably larger than any of the land outliers of Devon. Hitherto Portledge and Peppercombe in Barnstaple Bay, and Cawsand in Plymouth Sound, have been the most westerly points known of the English Trias. We are now enabled to carry it some fifty miles further to the south-west.

DISCUSSION.

The PRESIDENT pointed out the great interest of the facts observed by the Author, and thought that his conclusions were highly probable.

Rev. A. IRVING owned to a feeling of uncertainty as to whether the Author's conclusions could be regarded as well founded. He thought that the probability was that off the Lizard there are a number of erratic boulders, many of which may be derived from the Trias, but at the same time he indicated the difficulty of identifying these sandstone rocks when there was no palæontological evidence to go upon.

Mr. HUDLESTON thought the evidence of the rock being *in situ* was satisfactory.

Rev. A. IRVING remarked that large boulders would split along the bedding-planes.

26. A CONTRIBUTION to the HISTORY of the CETACEA of the NORFOLK "FOREST-BED." By E. T. NEWTON, Esq., F.G.S. (Read April 7, 1886.)

[PLATE XI.]

WHEN the Geological Survey Memoirs on the geology and palæontology of the country around Cromer were published, it was hoped they would awaken an increased interest in the collecting of fossils, more especially from the "Forest-bed Series," and thus be the means of increasing our knowledge of the fauna and flora of these deposits. Since that time there has been a more energetic collecting of "Forest-bed" fossils, with the result that several new forms have now to be added to our lists. My colleague, Mr. Clement Reid, has discovered a number of new plants, an account of which will shortly be published. Regarding the vertebrate fauna, perhaps the most remarkable addition has been that of the *Ovibos moschatus*, from Trimmingham, made known to us by Prof. W. Boyd Dawkins, who has also recognized *Cervus tetraceros* from West Runton (Quart. Journ. Geol. Soc. vol. xxxix. p. 575, and vol. xli. p. 243) and has likewise discovered a new form of deer from Kessingland, to be called *Cervus Savini* (Proc. Roy. Soc. vol. xxxviii. p. 345), the description of which has yet to be published. *Hycena crocuta* has been found at Corton Cliff (Geol. Mag. dec. ii. vol. x. p. 433), and Mr. Savin has fragments of this species from near Cromer. Several species which were not well authenticated have now been confirmed by additional examples: thus there is no longer any doubt as to the occurrence of *Cervus elaphus*, Mr. W. Davies, of the British Museum, having determined an antler in the collection of Mr. Backhouse, of York. The doubtful humerus of Wolf has now been supplemented by a part of a jaw from East Runton and a piece of tibia from Kessingland.

The latest acquisition has been made by Mr. Clement Reid, who, during a recent holiday on the Norfolk coast, purchased from a fisherman a tooth which had just been washed out of the "Forest-bed" at Sidestrand (Pl. XI. fig. 1); this he recognized as new to the deposits, and thinking that it was probably Sperm-Whale, kindly left it with me for determination. There is no doubt as to the horizon of this specimen; for although found on the shore just after a storm, as, indeed, is the case with most of the vertebrate fossils of this deposit, it has, cemented to it by iron pyrites, the peculiar white sandy matrix of the "Forest-bed." This tooth is in a very perfect condition, only the thin edges of the pulp-cavity being broken away, and this has evidently been done by rolling on the shore subsequent to removal from its resting-place. The summit has been rounded by wear during life, in a manner similar to that which is seen in the teeth of the recent Sperm-Whale; and the external surface, which is partly obscured by the incrusting sandy matrix, presents a number of irregular longitudinal grooves, especially noticeable towards the base. There is a slight, but distinct double curvature,

and the entire tooth is flattened from side to side, particularly in the region of the pulp-cavity, the flattening being natural and not due to post-mortem compression. The greatest thickness of the tooth is at a little more than a third from the apex, and from this region to the base it becomes rapidly compressed. The large size of the pulp-cavity and the entire absence of globular osteodentine show that the tooth was not fully developed. The proportion of dentine to cement is shown in the section (Pl. XI. fig. 2). At the middle of the tooth, where the larger diameter is 2.35 in., the dental core has a diameter of 1.7 in., and the cement is about 0.3 in. thick on each side.

Measurements.

	inch.
Greatest length of tooth	5.8
Greater diameter, one third from base	2.5
Lesser diameter, one third from base	1.6
Greater diameter, one third from apex	2.2
Lesser diameter, one third from apex	1.75
Greater diameter at base	2.6
Lesser diameter at base	1.3
Pulp-cavity extends from base	2.65

Thin sections examined with the microscope show the dental tubules passing obliquely upwards from the axis with slight undulations, and giving off at intervals fine anastomosing branches; just before reaching the cement layer the tubules become finer and terminate in the granular layer, a more opaque band in which the structure is obscure. Throughout the dentine, and especially towards the periphery, the globular calcigerous cells are more distinct than is usually the case in mammalian teeth; but this peculiarity seems to be shared by other forms of marine mammals.

The minute characters of the cementum are remarkable, and although repeated, in a less marked degree, in some recent forms, they do not seem to have been fully described. Polished sections of the cement, even when examined with a pocket lens, show series of laminae, and under the microscope thin sections show these to be composed of alternating, more or less transparent bands. In a transverse section, besides the lacunae, which are arranged on the whole parallel to the laminae, there are numerous "Sharpey's fibres" which cross the bands. For the most part, these fibres are far larger than the tubules of the dentine, and much less regular in size and direction; passing from the inner side they undulate, crossing and recrossing one another so as to produce a complex plaited appearance. In a longitudinal section the undulations are seen to be much more deeply curved (fig. 3, *b* to *c*). The fibres do not remain of the same size throughout, but are enlarged at intervals, and becoming more opaque produce the appearance of spindle-shaped bodies. When these bodies are examined with a power of 200 diameters or more (fig. 4) they may be seen to contain one, two, or perhaps three rows of indistinct spherules, which are probably calcigerous cells. The

greater number of these spindles are aggregated in certain of the laminae and, indeed, seem to be the cause of the greater opacity of the darker bands.

The examination of some very thin sections of a recent Cachalot's tooth failed at first to reveal these spindle-shaped bodies; but a closer examination of more carefully prepared sections showed that the spindles were present, although not so obvious as in the fossil, and they seemed to contain but one or perhaps two rows of calcigerous cells. Probably the condition of fossilization has much to do with the distinctness of these bodies, which I have detected in the thick cement of some other forms of mammals. With the exception of this variation in the structure of the cement, I see no difference worth mentioning between this "Forest-bed" fossil and the tooth of a recent Sperm-Whale. The presence of globular osteodentine in the basal portion of the Cachalot's tooth is no doubt characteristic; but its absence from the "Forest-bed" specimen does not militate against the latter belonging to the same species; for it is obvious that there must have been a time with every tooth when the osteodentine had not begun to be formed, and this fossil is doubtless a young tooth in that condition. The absence of globular osteodentine from the *Physeteroid* teeth of the Red Crag, which have been called by Sir R. Owen *Balenodon physaloides*, cannot be taken as evidence of their affinity with the "Forest-bed" specimen; for not only does it happen that osteodentine is sometimes present in the Crag teeth, but the outward form of these fossils is different, being more slender and cylindrical, and having always a proportionately smaller core of dentine and a larger development of cement, notwithstanding that there is much variation in the latter particular.

With the exception of the Cachalot's tooth noticed by Sir R. Owen (Brit. Foss. Mamm. p. 524), as from "the superficial deposits near the coast of Essex," which is of doubtful age*, I am not aware that the Sperm-Whale has ever been noticed as a fossil in this country. M. Gervais records several *Physeter* teeth from the Pliocene of Montpellier and of Gironde (Gervais and Van Beneden, 'Ostéographie des Cétacés,' 1880, p. 329, and Zool. et Pal. Fr. p. 285), but these, being of a different form, have been doubtfully referred to another species, *Physeter antiquus*.

At the present day the Sperm-Whale inhabits the tropical and warmer temperate latitudes, but wanders occasionally both northwards and southwards. Numerous instances are on record of its having been found on our own coasts; the last, according to Bell (Brit. Quadrupeds, 1874, p. 418), was stranded in Loch Scavaig, I. of Skye, in 1871. The species is not altogether unknown on the

* There can be little doubt that the figure of this tooth given in the 'British Fossil Mammals' at page 524 was drawn from the specimen in the Hunterian Museum, Roy. Coll. Surgeons, no. 2887, which in the catalogue is said to have been presented by Mr. Darwin, and to be from S. America. This could not have been the tooth to which Mr. Charlesworth referred in 1884 (Quart. Journ. Geol. Soc. vol. i. p. 40, 1845), which was doubtless one of the Red-Crag *Balenodon* teeth.

Norfolk coast; for Mr. T. Southwell ("Fauna of Norfolk," Trans. Norf. and Norwich Nat. Hist. Soc. vol. i. p. 71) refers to a record of a Sperm-Whale being washed on shore at Wells, and another at Hunstanton, early in the 17th century.

Another interesting example of a "Forest-bed" fossil Cetacean (Pl. XI. figs. 5, 7) is in the possession of Mr. Jas. Backhouse, of York, who has been good enough to allow me to make use of it for these notes. The specimen is a portion of the ankylosed cervical vertebræ of a large Whale, belonging to a genus not hitherto recognized in these Norfolk deposits. Before describing this fossil, it will be well to give some explanation of its condition and origin. The presence of oysters and polyzoa on the surface would lead one to suspect that it had been dredged, and that its age was therefore uncertain; such, however, is not the case. The fossil was obtained through Mr. A. Savin, of Cromer; and in a letter he tells me that this mass of vertebræ came from a low ledge of rocks ("Forest-bed") opposite Overstrand, near Cromer, which is only exposed at very low spring-tides; and as these rocks would be for a greater part of the time in deep water, the presence of oysters &c. adhering to the specimen is fully accounted for; moreover other examples of fossil bones covered with marine organisms have been obtained from the same spot. I am the more anxious to call attention to these facts because bones and teeth in a similar condition to this specimen are not uncommon in collections, and although many of them have doubtless been dredged, this is not always the case, and such specimens may be true "Forest-bed" fossils.

Mr. Backhouse's specimen is the right half of the seven cervical vertebræ of a Whale, so closely ankylosed that only the slightest trace of their original distinctness is now discernible. The centra have been broken through longitudinally and vertically, as nearly as may be, in the middle line, and all the neural arches and processes have been more or less broken away; but sufficient remains to enable one to trace the positions of the six intervertebral foramina and thus to show that seven vertebræ are combined to form the mass (fig. 5). Between these foramina, or grooves as they now are, may be seen the surfaces from which the neural arches have been broken away. Judging from these broken surfaces, the first neural arch and superior transverse process were far larger than any of the others. The second neural arch seems to have been next in point of size, and then the seventh and fifth. The third, fourth, and sixth are nearly of the same size and smaller than the others. The first and second superior transverse processes seem to have been closely united. The inferior transverse process of the second vertebra was large, as indicated by the broken base; those of the third and fourth vertebræ were slender, while the hinder three vertebræ have no trace whatever of inferior transverse processes. The double cup of the atlas for the reception of the condyles of the skull must, when perfect, have been at least 17 inches across (the one half being a little more than $8\frac{1}{2}$ inches). The outer edge of the cup is to some extent denuded.

The upper surfaces of the centra are nearly flat from side to side, except at the front, where the median region sinks down into the depression seen between the cups of the atlas. In a side view (fig. 5) the upper surface makes a regular sweep from the hinder part, and is continued upwards towards the top of the atlas. The hinder surface of the seventh centrum is concave and, in outline, flattened from above downwards; but as it is a little broken both at the top and bottom, the exact form is disguised. The width of this surface, when complete, was probably $10\frac{1}{2}$ or 11 inches.

Measurements.

	Forest-bed fossil.	<i>Balæna mysticetus.</i> Coll. Surg. 2744.	<i>Balæna biscayensis?</i> Brit. Mus. 338, f.
Across both cups of atlas.....	in. 17	in. 15.5	in. 14
Fore and aft length of lower surface of centra	9	11.0	9

The cervical vertebræ of Cetacea vary much as to the extent to which they become ankylosed together, and these variations are very characteristic of the different genera. Among recent Whales the only forms large enough to render a comparison of them with this fossil desirable are *Balenoptera*, *Megaptera*, *Balæna*, and *Physeter*. In the first of these the cervical vertebræ, as a rule, remain separate; but in exceptional cases two or three may be united. *Megaptera* generally has two or three of the neck-vertebræ fixed together. *Balæna* has all seven cervical vertebræ soldered into one mass; but the divisions between the bodies are generally, if not always, distinctly seen. In *Physeter* the first vertebra (atlas) is always free, but the hinder six are more closely united than in any other form.

The "Forest-bed" fossil has the seven cervical vertebræ closely united, and it is obvious therefore that it comes nearer to *Balæna* than to any of the other genera mentioned. There are three examples of the united cervical vertebræ of *Balæna mysticetus* available for comparison in the Museum of the Royal College of Surgeons, which, by the courtesy of Prof. C. Stewart, I have been able to examine and measure. In most of their characters these specimens agree with Mr. Backhouse's fossil; but in none of them are the divisions between the vertebræ so completely obliterated. As regards the number of inferior transverse processes, there is much variation to be observed among them, and even the two sides of a specimen do not always agree. It is evident from this and other differences that a wide allowance must be made for individual variation. The point in which these specimens seem most to differ from the fossil is in the concavity of the upper surfaces of the centra.

This concavity is such that the intervertebral foramina are raised much above the level of the floor of the neural canal, and this is not the case in the fossil. Even in this particular, however, there is some difference among the recent examples; but in none of them is the upper surface so flat as it is in the fossil.

In the Cetacean Gallery of the British Museum, South Kensington, there is a specimen of the cervical vertebræ of a *Balæna*, labelled *B. biscayensis* (no. 338, f.), which has the upper surfaces of the vertebræ more flattened, and therefore agrees better with this fossil. There is one important point, however, in which this, as well as the *B. mysticetus*, differs from this fossil, and that is in the proportion between the width across the cups of the atlas and the length of the vertebral centra measured along their lower surfaces, as shown in the table of measurements on page 320.

The British-Museum specimen, which was dredged off Selsey, was referred by Dr. Gray at first to *Balæna biscayensis*, but afterwards to a new species, and subsequently to a new genus (Proc. Zool. Soc. 1873, p. 140). In the latest catalogue of the British-Museum Cetacea (by Prof. Flower, 1885) this specimen, in the absence of sufficient evidence for separation, is included provisionally under the name of *Balæna australis*.

By some authors *B. biscayensis*, *B. australis*, and *B. antipodarum* are regarded as distinct species; but their cervical vertebræ, as figured by Gervais and Van Beneden (Ostéographie des Cétacés, pls. i., iii., and x.), do not show differences which can be taken as definitely specific.

The fossil forms of *Balæna*, *Balænnula*, and *Balænotus* described by Van Beneden ("Ossem. Foss. d'Anvers," Ann. Mus. Roy. Hist. Nat. Belg. tome iv. part 2, 1880) may have some resemblance to the "Forest-bed" fossil, but are less nearly allied to it than some of the recent forms.

Mr. Backhouse's specimen is certainly a *Balæna*, and possibly may represent a new species; but bearing in mind the uncertainty which exists as to the living species of the genus, it is better not to give a new name, but to refer the fossil provisionally to one of the recent species. It is generally agreed that in the northern hemisphere there are two true whalebone Whales—one the *Balæna mysticetus*, which is only found in high northern latitudes and always in the neighbourhood of ice; the other, which has been named *B. biscayensis*, is believed to be the form that, until quite modern times, was an inhabitant of our own seas. At present there is some doubt as to the southern species, *B. australis* and *B. antipodarum*, being distinct from *B. biscayensis*; but their identity has yet to be established. *Balæna mysticetus* may, like some other northern mammals, have found its way further south in later Pliocene times than it does at the present day, and it is just possible that this fossil might belong to that species; but the available evidence seems rather to favour its being referred provisionally to *B. biscayensis*.

In the Survey Memoir on the "Forest-bed" Vertebrata two large Cetacean vertebræ were noticed; but in the absence of sufficient

evidence they were not named, but provisionally left where one of them had already been doubtfully placed, that is, in the genus *Balænoptera*. As we now know of two other genera of Whales in the "Forest-bed," *Physeter* and *Balæna*, the question arises, may not these vertebræ belong to one of these forms? Let us take, in the first place, the vertebra from Cromer, belonging to Mr. W. Barker of Birmingham, to whom I am indebted for measurements and sketches which enable me to give the following particulars of this largest Whale vertebra with which I am acquainted. This specimen, which has lost all its processes, measures about 16 inches across the terminal face, and about $10\frac{1}{2}$ inches from front to back. There is a pair of surfaces below for the attachment of chevron bones, as well as evidence of the neural arches above, and at the side are the bases of the broken transverse processes. From this it is clear that we are dealing with a caudal vertebra which probably belonged to quite the anterior part of that region. The variations in the proportions of length to width in the vertebræ of the large Whales gives a clue to the genus to which they belong, and judged by this standard Mr. Barker's specimen agrees with the anterior caudal vertebræ of *Balæna*, as shown in the table of measurements (p. 323). It is quite possible that it belongs to the same species as the cervical vertebræ above described, with which it will for the present be associated.

The second large Cetacean vertebra is in Mr Gunn's collection in the Norwich Museum, and is from the "Forest-bed" of Bacton; it is almost as large as Mr. Barker's specimen, being nearly 15 inches in diameter. Mr. Gunn has most kindly supplied me with measurements and other information concerning this vertebra. The two surfaces from which the neural arch has been broken away are seen on the upper part, and at the sides are the bases of the transverse processes. In the middle of the lower surface there is an irregular thickened projection, which seems to be the characteristic ridge of the Whale's lumbar vertebræ. Neither in form nor in the proportion of length to breadth does this vertebra agree with the lumbar vertebræ of either *Physeter* or *Balæna*. Its measurements, however, agree fairly well with the lumbar vertebræ of *Balænoptera*; and, although the inferior ridge is stronger than in either of the recent skeletons I have been able to examine, it seems highly probable that it belonged to a species of that genus.

Other Cetacean vertebræ of smaller size have been found in the "Forest-bed;" but with the exception of the two forms already referred to *Delphinus* (Survey Memoir), their affinities have not been determined.

The following list includes all the Cetacea at present known to occur in the "Forest-bed":—

- Balænoptera, sp., from Bacton.
- Balæna biscayensis, from Overstrand.
- Physeter macrocephalus, from Sidestrand.
- Monodon monoceros, from Mundesley.
- Delphinus delphis, from Overstrand.
- sp. (near to *D. tursio*), from Overstrand.

Table of Measurements.

		Transverse diameter.	Length.	Percentage of length to breadth.
Vertebra in Mr. Barker's collection ...		in. 15.75	in. 10.5	66.6
Vertebra in Mr. Gunn's collection		14.5	11.0	75.8
<i>Balenoptera</i> , sp., in the College of Surgeons Mu- seum, no. 2754	1st lumbar	11.5	9.5	82.6
	7th lumbar	11.5	10.0	86.9
	15th lumbar	12.5	11.25	90.0
	1st caudal	12.5	11.0	88.0
	5th caudal	12.5	11.0	88.0
<i>Balenoptera mus- culus</i> , in British Museum.....	1st lumbar	13.0	10.0	76.9
	5th lumbar	13.0	10.25	78.8
	1st caudal	14.0	12.5	89.2
	5th caudal	14.5	12.75	87.9
<i>Balenoptera Sib- baldi</i> , in British Museum.....	4th lumbar	12.5	8.25	66.0
	1st and 2nd caudal	13.5	10.25	75.9
	5th caudal	13.5	10.25	75.9
<i>Physeter macro- cephalus</i> , in British Mu- seum	1st lumbar	14.0	9.5	67.8
	5th lumbar	14.0	10.0	71.4
	1st caudal	14.0	12.0	85.7
	5th caudal	13.75	11.25	81.8
<i>Balæna</i> , sp., Col- lege of Surgeons, no. 2750.....	caudal	12.75	8.5	66.6
	caudal	13.0	8.5	65.3

EXPLANATION OF PLATE XI.

- Fig. 1. *Physeter macrocephalus*. Tooth from the "Forest-bed" of Sidestrand. Presented by Mr. Clement Reid to the Museum of Practical Geology. $\frac{4}{5}$ natural size.
2. Same specimen, cut through longitudinally, to show pulp-cavity and proportion of dentine and cement.
 3. Same specimen. Longitudinal section of portion of dentine and cement, enlarged 20 diameters, to show the interlacing of the spindle-shaped "Sharpey's fibres." *a* to *b*, dentine; *b* to *c*, cementum.
 4. Same specimen. A few of the "Sharpey's fibres," with a few lacunæ, from lamina *d* in fig. 3, enlarged 215 diameters.
 5. *Balæna biscayensis*. Side view of the right half of seven ankylosed cervical vertebræ, wanting the processes and neural arches, from the "Forest-bed" of Overstrand, near Cromer, in the collection of Mr. Jas. Backhouse, of York. $\frac{1}{4}$ natural size.
 6. Same specimen, with neural arches restored in outline. $\frac{1}{8}$ natural size.
 7. Same specimen, front view. $\frac{1}{4}$ natural size.
 8. Same specimen, front view, with the neural arch and processes restored in outline. $\frac{1}{8}$ natural size.

DISCUSSION.

PROFESSOR FLOWER said Mr. Newton's descriptions were very careful and exhaustive. Unfortunately, in the case of the larger

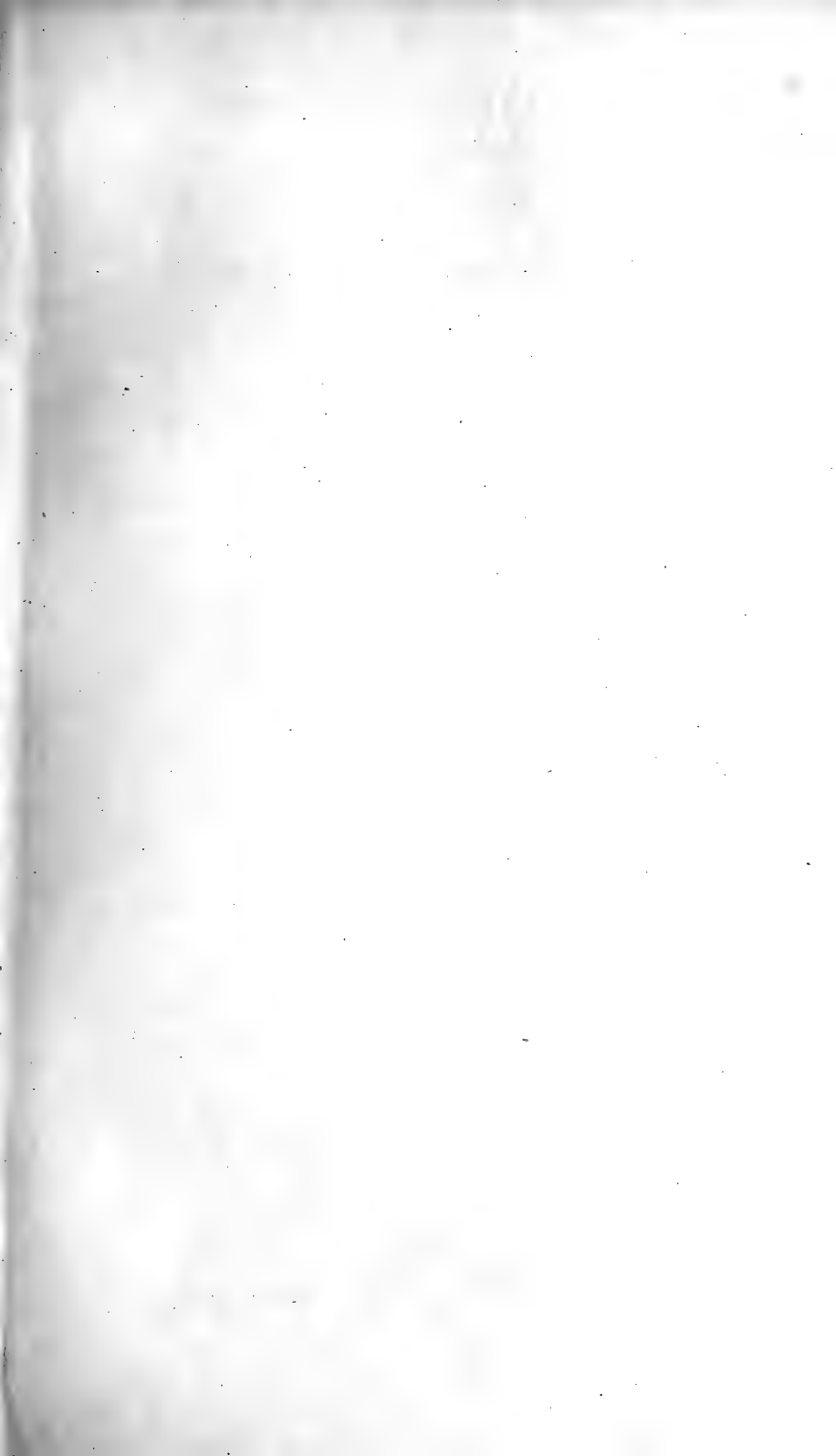
Cetacea, despite the large number of specimens recently added to our collections, there was still a want in this country of sufficient materials for comparison. *Balæna biscayensis* had almost died out without specimens being procured, but fortunately it seemed to have lately increased in numbers. Whales varied much individually, and one skeleton of each species was insufficient for comparison.

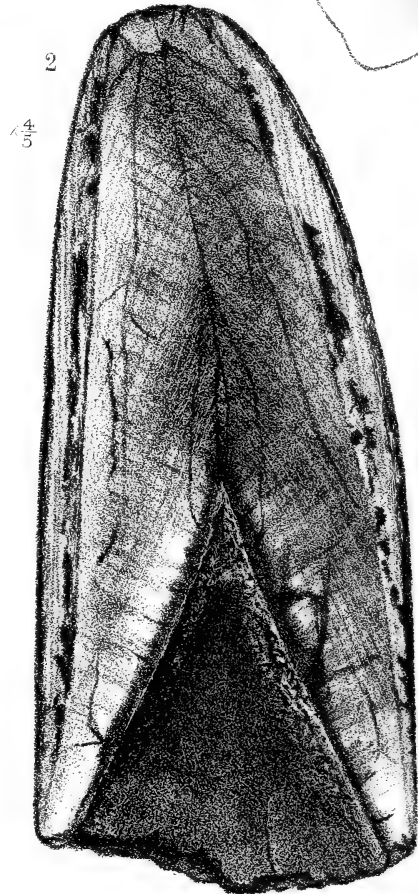
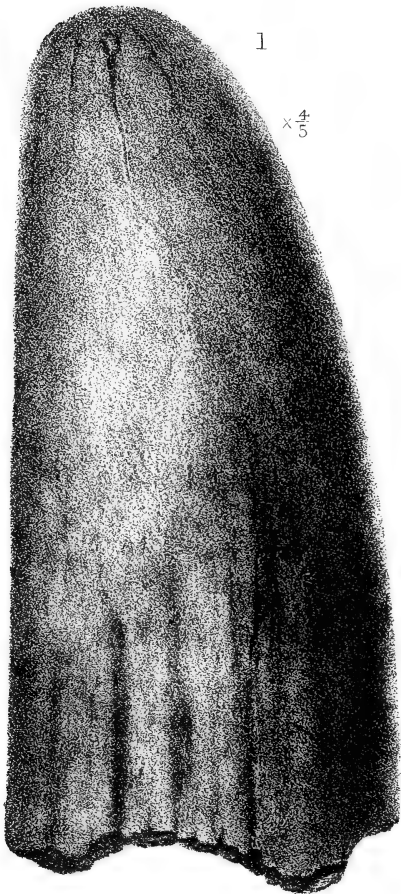
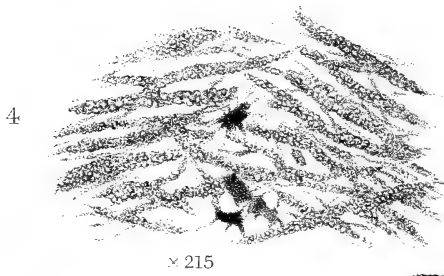
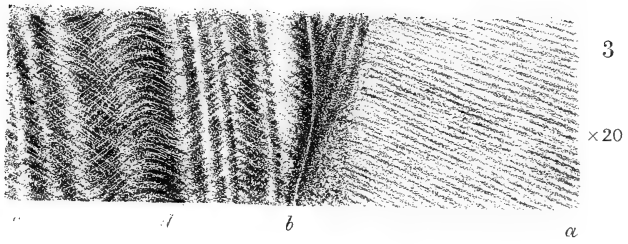
With the general conclusions of the Author the speaker agreed. He saw no reason for distinguishing the tooth on the table from that of the Common Sperm-Whale. He doubted whether *Balæna biscayensis* differed from *B. australis*; but perhaps it was safer to refer the specimen described to the first-named species. Mr. Newton's collection gave a fair epitome of the Cetaceans inhabiting British seas, as it contained examples of all the leading types.

Dr. WOODWARD inquired whether the remains might not be rather later in time than the true Forest-bed age, especially if the latter was a land period, and referable to the time when the Forest-bed was being again submerged.

Mr. CLEMENT REID thought the bones came from the Forest-bed, as they agreed with specimens from that deposit in the state of mineralization. He obtained the Sperm-Whale tooth himself from a fisherman who had just found it, and he described the circumstances. It was noteworthy that the large land-mammals of the Forest-bed were extinct, whilst the Cetaceans appeared to be of recent species.

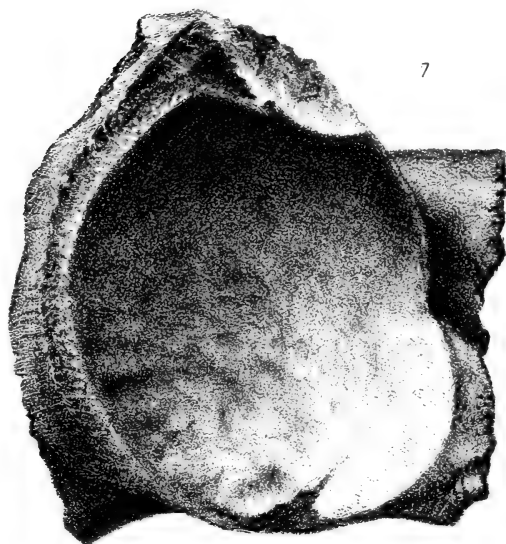
The AUTHOR thanked Prof. Flower for his remarks, and acknowledged his indebtedness to Prof. Flower's writings in the working out of these fossils.







$\times \frac{1}{8}$



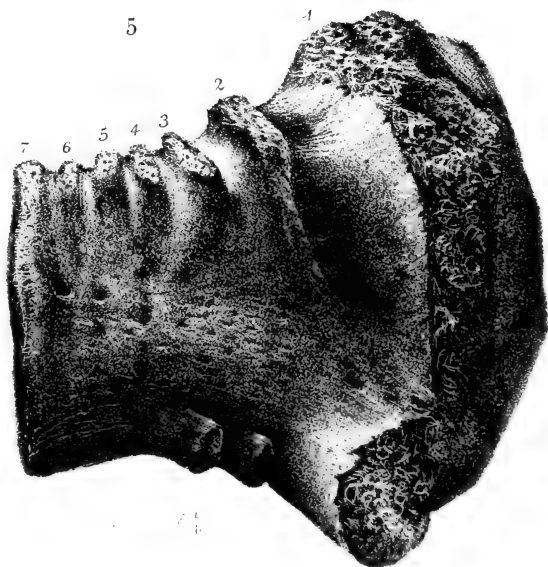
7

$\times \frac{1}{4}$



6

$\times \frac{1}{8}$



5

1

2

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4

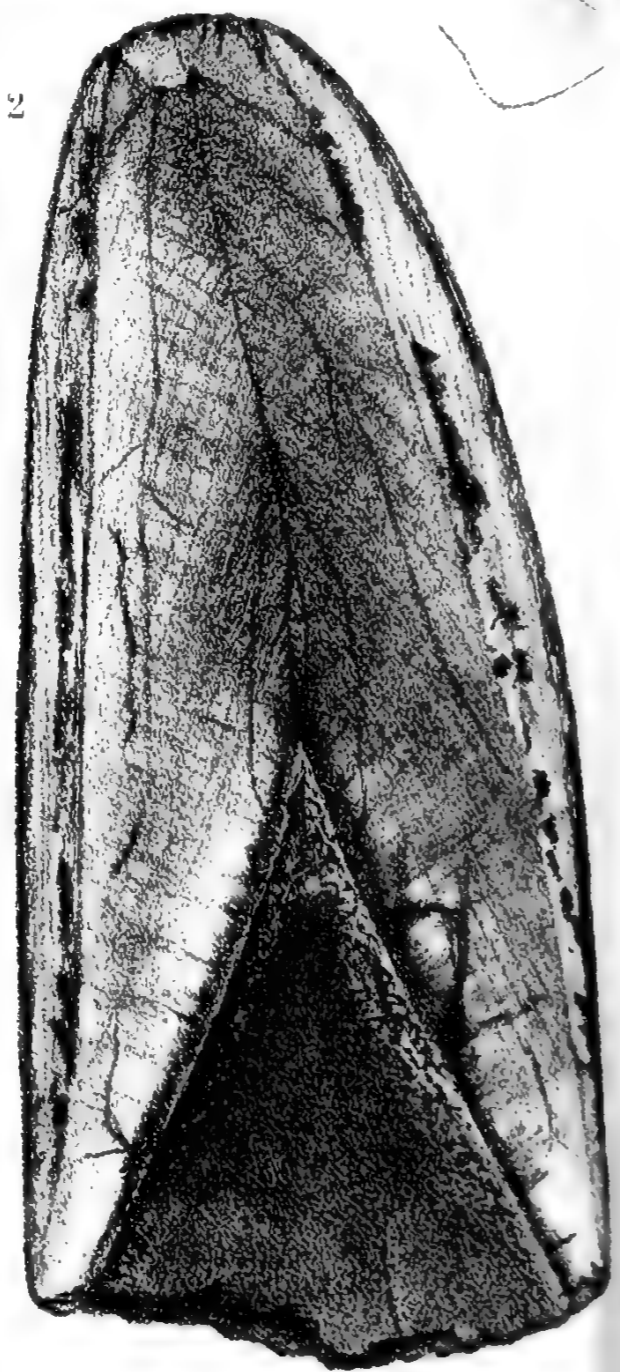
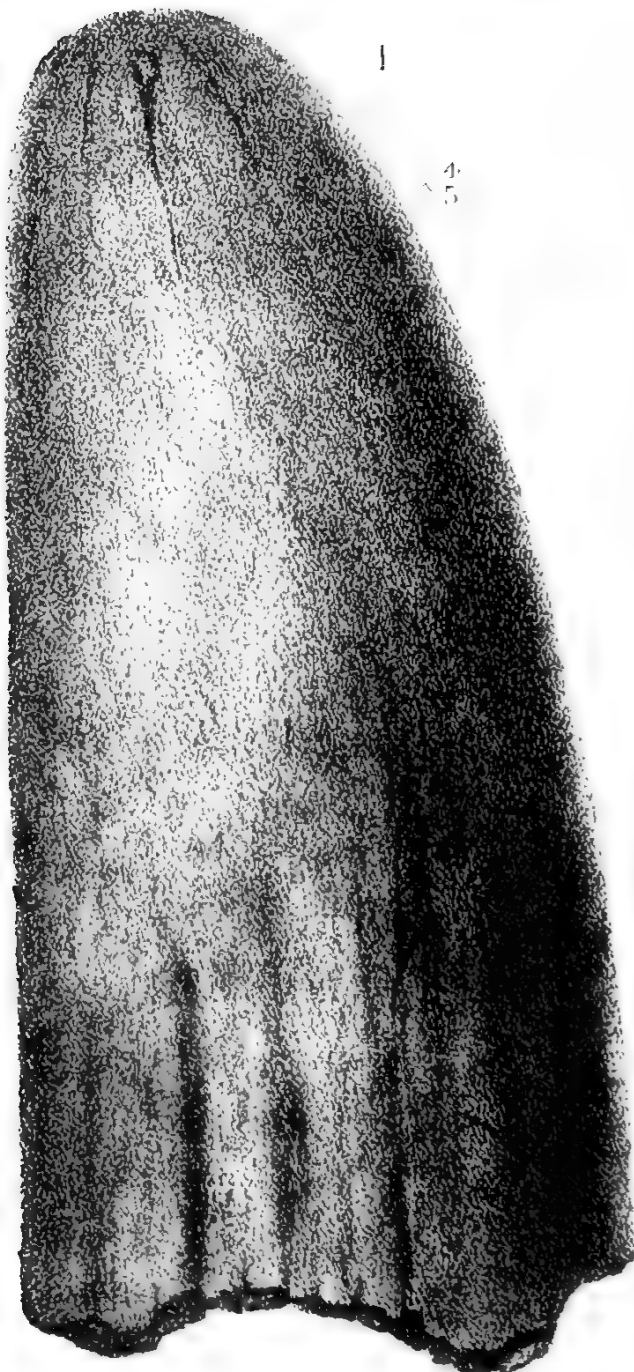
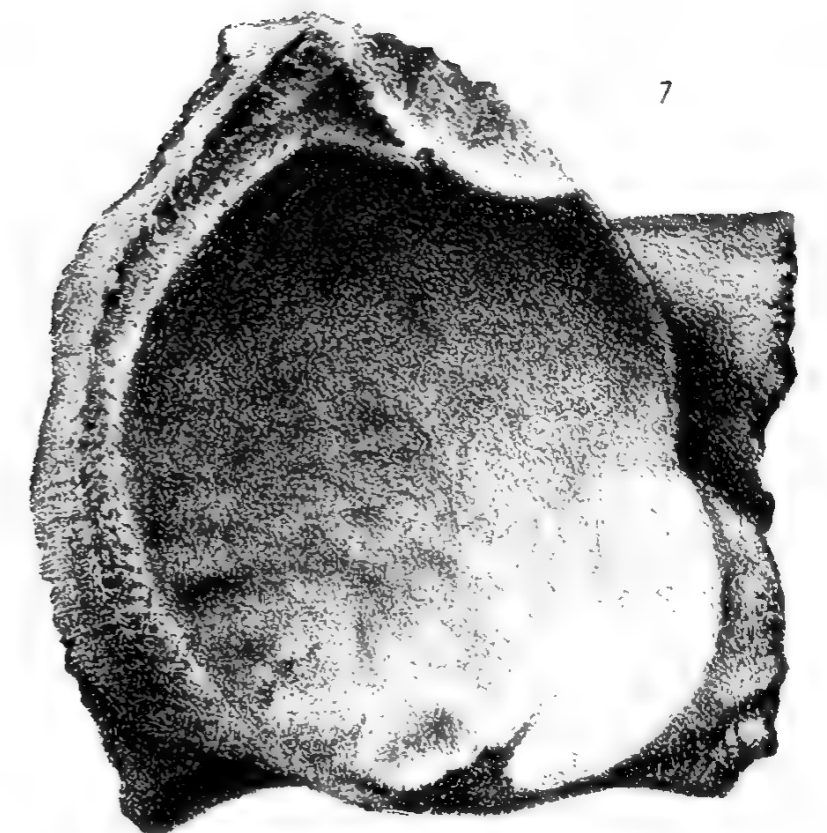
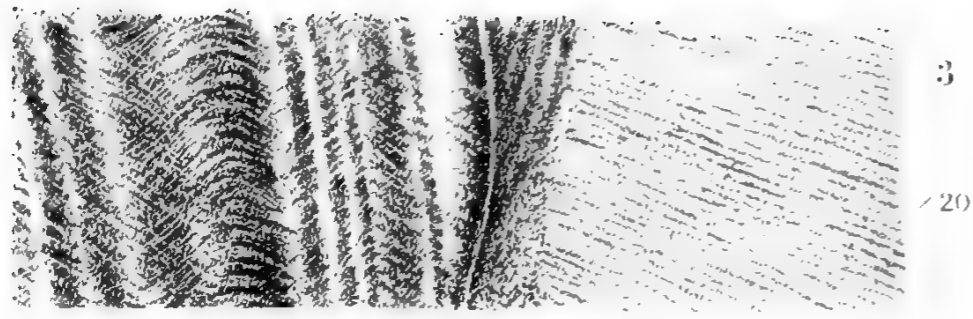
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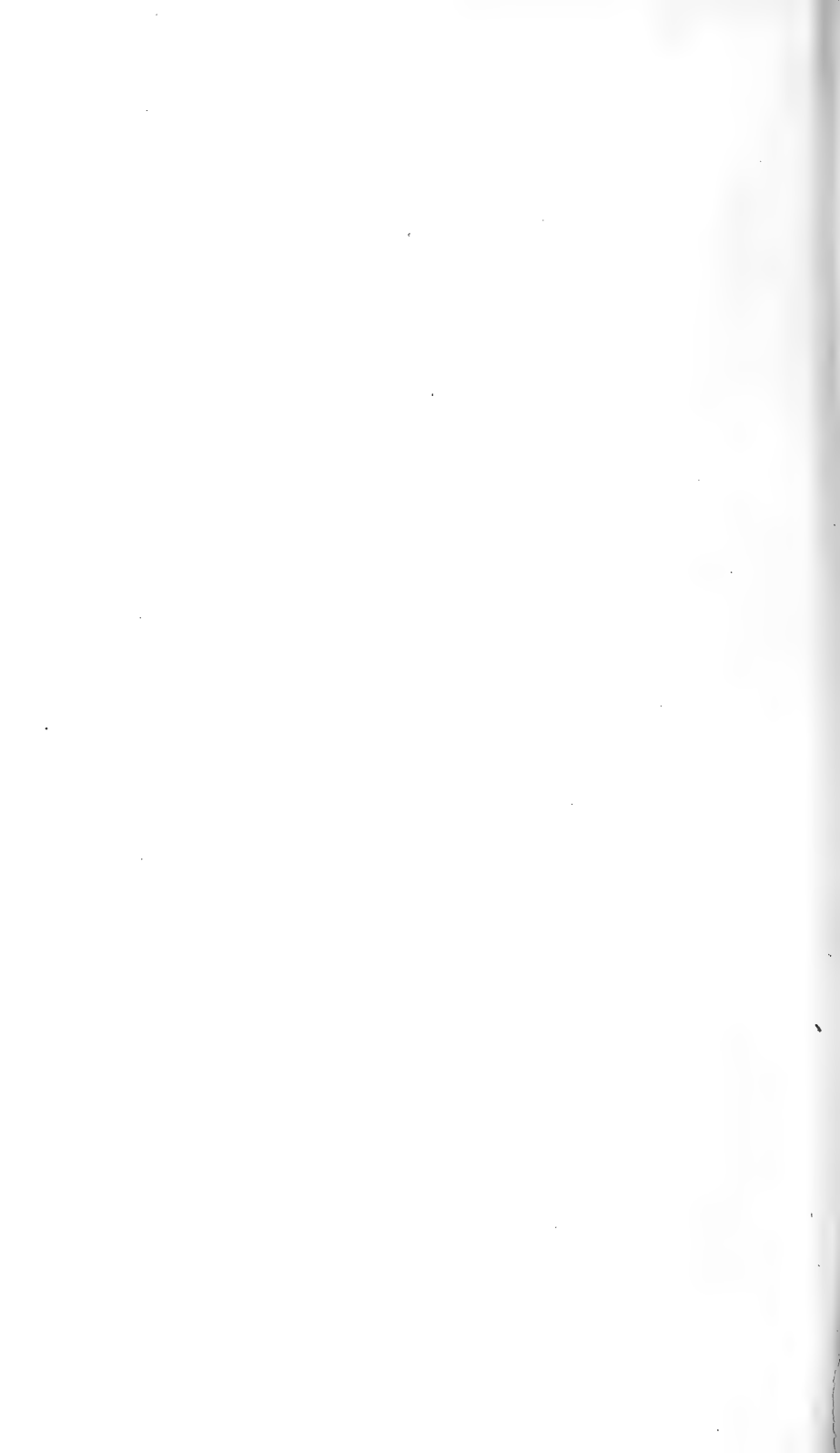
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27. *On the UPPER CRETACEOUS SERIES and the PHOSPHATIC BEDS in the NEIGHBOURHOOD of MONS (BELGIUM).* By M. F. L. CORNET, Member of the Royal Academy of Sciences of Belgium, Foreign Correspondent of the Geological Society of London, &c. (Read April 21, 1886.)

THE increasing importance of the use of phosphate of lime in agriculture induces me to give to English geologists some account of the beds that have been worked in Belgium during the last few years.

The phosphatic beds of which I wish to speak are situated in the province of Hainaut, near to the town of Mons, on the lands of the Communes of Cuesmes, Ciply, Mesvin, Nouvelles, Spiennes, Saint Symphorien, and Havré. This part of Belgium is traversed by numerous railways and by a canal which enables boats of from 200 to 300 tons to penetrate to the centre of France, and to reach the ports of Ghent, Ostend, Antwerp, Dunkirk, &c.

The working of the phosphate of lime began in 1870, and its production, small at first, was not developed until 1877. The following figures will show its increase from that date:—

1877.	Production in English tons ..	3,850
1878.	" " "	5,630
1879.	" " "	7,578
1880.	" " "	15,500
1881.	" " "	29,528
1882.	" " "	40,043
1883.	" " "	58,660
1884.	" " "	85,000

A large portion of this mass was sold in Great Britain and Ireland, about 35,000 tons having been sent there in 1883.

It is probable that the annual yield will soon exceed 100,000 tons; but the description which I am about to give will show that a much higher figure may be reached.

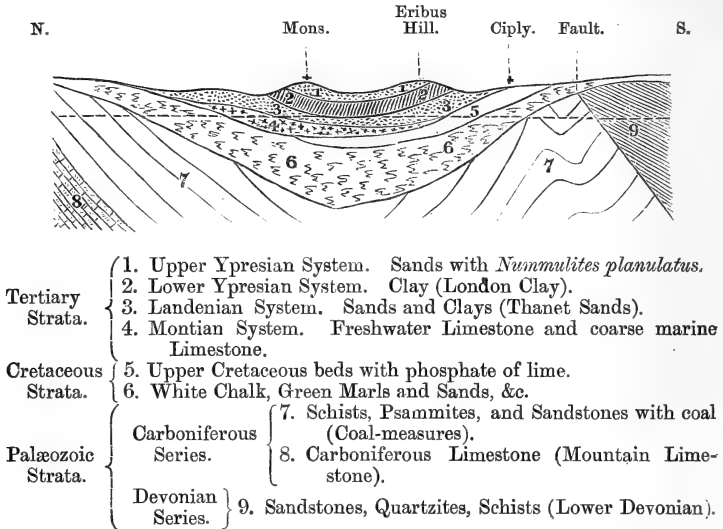
Our beds of phosphate of lime occur in the Upper Cretaceous series, the thickness and variety of the strata which constitute it attaining greater importance in the neighbourhood of Mons than in any other part of Western Europe.

The Cretaceous series of the province of Hainaut belongs to the great Anglo-French geological basin. It is deposited in a long and deep valley excavated in the Coal-measures, its direction being from east to west. The deposits of chalk which have filled this great trough have subsequently been partly denuded. A new valley has been formed in it, also with its direction from east to west; this has been filled up by Tertiary beds, which in their turn have been partially removed by the quaternary water-currents which

have excavated the existing valley in which the river Haine likewise flows from east to west.

The subjoined diagram (fig. 1) gives a general idea of the superposition of these beds. It is taken from north to south and passes by the town of Mons, situated on an isolated hill in the middle of the valley of the Haine.

Fig. 1.—Section through the Haine Valley.
(Vertical scale 1 : 20,000 ; horizontal scale 1 : 160,000.)



The denudation which has excavated the valley in which the Tertiary strata are deposited has cut deeply into the Cretaceous beds, but has left intact on the southern slope the zone marked No. 5 in our diagram. This zone contains the phosphatic beds, which I now proceed to describe.

In their various geological publications, M. Briart and the author of this paper have established in the Cretaceous series of the province of Hainaut six great divisions or stages which they have subdivided into groups. The two upper stages are constituted as follows :—

- | | | |
|------------|---|---|
| 6th Stage. | { | Tufaceous Chalk of Ciply (Tufeau de Ciply). |
| | | Malogne Conglomerate (Poudingue de la Malogne). |
| | | Brown Phosphatic Chalk of Ciply. |
| 5th Stage. | { | Coarse Chalk of Spiennes. |
| | | White Chalk of Nouvelles. |
| | | White Chalk of Obourg. |
| | | White Chalk of Trivières. |
| | { | White Chalk of St. Vaast. |

I shall only discuss here the beds above the White Chalk of Obourg.

The deposit of White Chalk of Nouvelles is formed of very pure white chalk, containing from 98 to 99 per cent. of carbonate of lime. Nodules of black flint are of frequent occurrence. The principal fossils met with are :—

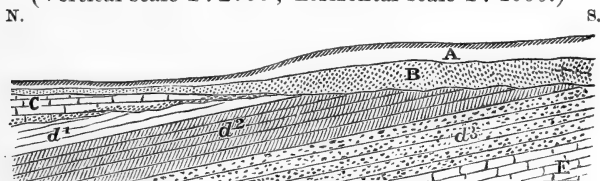
Belemnitella mucronata, *Schl.*
Ostrea vesicularis, *Lamk.*
Pecten cretosus, *Defr.*
Terebratula carnea, *Sow.*
Magas pumilus, *Sow.*

Rhynchonella octoplicata, *Sow.*
 — *subplicata*, *D' Orb.*
Echinocorys vulgaris, *Breyn.*, var. *ovata.*
Offaster pilula, *David.*
Micraster Brongiarti, *Héb.*

M. Briart and I have correlated the Chalk of Nouvelles with the Chalk of Meudon of French geologists.

It is useless for the purpose of this paper to describe the beds which underlie the White Chalk of Nouvelles; I shall, however, give the details of the strata which overlie it. For this purpose I will make use of the Section fig. 2, which is the exact representation of the beds uncovered in the quarries between Mesvin and Cipay.

Fig. 2.—Section near Cipay and Mesvin.
 (Vertical scale 1 : 2000 ; horizontal scale 1 : 4000.)



There occur successively in descending order :—

- A. *Quaternary Strata*.—Loam adapted for brick-making overlying sandy loam, below which sand with gravel is often met with. In this gravel flints worked by man have been found, and numerous fossil bones, belonging chiefly to—

<i>Elephas primigenius.</i>	|	<i>Equus caballus.</i>
<i>Rhinoceros tichorhinus.</i>	|	<i>Cervus elaphus.</i>

- B. *Tertiary Strata*.—Lower portion of the Landenian system of Dumont, corresponding with the Thanet Sands of English geologists. It is composed of glauconiferous sands, the upper part of which is loose, while the lower is very argillaceous and compact. The following fossils are found in it—

Gastornis Edwardsii, *Lemoine.*
Pholadomya Koninckii, *Nyst.*
Cyprina Morrisii, *Sow.*

At the base of the bed B a pebbly deposit is often found containing flints, well rounded and mixed with nodules, sometimes very large, of the same substance, and evidently derived from the destruction of the Cretaceous strata. This deposit rests upon the Cretaceous series (E) in the quarry where the section, fig. 2, was taken; but

on the opposite slope of the great valley, that is to say under the town of Mons and northward, the Landenian system is separated from the Cretaceous series by a very considerable thickness of highly fossiliferous marine calcareous freestone, known by the name of Calcaire grossier de Mons, and by marls and freshwater limestone with *Physa*, belonging to the Tertiary series. These deposits constitute the stage to which Belgian geologists have given the name of the Montian system (Système Montien). See fig. 1, No. 4.

C to E. *Cretaceous Series.*

C. *Tufaceous Chalk of Cibly.*—This is a calcareous rock of coarse texture, somewhat friable, white or slightly yellowish, chiefly composed of carbonate of lime. It forms thin beds regularly stratified, in which are occasionally found nodules of grey flint.

The Tufaceous Chalk of Cibly is the geological equivalent of a part of the *Tufaceous beds of Maestricht*. The following are some of its characteristic fossils :—

<i>Ostrea vesicularis</i> , Lamk.	<i>Argiope Davidsoni</i> , Bosq.
— <i>lateralis</i> , Nils.	<i>Terebratulina striata</i> , Wahl.
<i>Janira quadricostata</i> , d'Orb.	<i>Pentagonaster quinquelobus</i> , d'Orb.
<i>Crania Davidsoni</i> , Bosq.	<i>Hemipneustes striato-radiatus</i> , d'Orb.
— <i>comosa</i> , Bosq.	<i>Cassidulus elongatus</i> , Agass.
— <i>nodulosa</i> , Hömigh.	<i>Catopygus pyriformis</i> , Agass.
<i>Thecidea papillata</i> , Bronn.	<i>Temnocidaris danica</i> , Cotteau.
— <i>longirostra</i> , Bosq.	<i>Porosphora nuciformis</i> , Goldf., sp.
— <i>recurvirostra</i> , DeFrance.	<i>Trochosmilia Faujasi</i> , Edw. & H.

With these species are found numerous Polyzoa. At many places in quite the lower part of these beds a conglomerate occurs, its thickness varying from some inches to several feet. It is formed of brown nodules, re-united by a more or less coherent paste of carbonate of lime. The greater number of the nodules have a diameter from $\frac{1}{10}$ in. to 2 inches. Their chemical composition, determined by M. Peterman, director of the Agricultural Station of Gembloux, is as follows * :—

Lime	51.22
Magnesia.....	1.30
Oxide of Iron and Alumina	2.56
Potash	0.21
Soda.....	0.53
Carbonic acid	18.61
Sulphuric acid	1.36
Phosphoric acid	22.48
Silicic acid	1.14
Insoluble matter in the oxides	0.22
Organic mater. Traces of Fluorine and }	0.37
Chlorine	
	100.00

This conglomerate is that to which the name of "Poudingue de

* Bulletin de l'Académie Royale de Belgique, 2^e sér. vol. xxxix.

la Malogne has been given." Several attempts to work the phosphate of lime had soon to be abandoned on account of the irregularities of the bed.

This conglomerate of Malogne has been proved to be extremely rich in fossils at certain spots in the neighbourhood of Cibly; but the most abundant species are found also in the Tufaceous Chalk, or in the brown phosphatic chalk which I am about to describe*.

D. *Brown Phosphatic Chalk of Cibly*.—It may be described in three subdivisions, which are:—

*d*¹. Calcareous rock of coarse texture, whitish, rough to the touch, somewhat friable, and stratified in regular beds. There are a few continuous beds of grey flint. The upper strata consist almost entirely of carbonate of lime. Below there are beds in which brown phosphatic grains appear mingled with some grains of glauconite. The quantity of phosphate increases in going deeper, and thus we arrive, without any sudden transition, at the veritable brown phosphatic chalk. Total thickness from 20 to 30 feet.

The fauna of the beds *d*¹ is the same as that of the lower deposit, *d*². Some species, however, occur there in greater abundance. I may name, amongst others, *Thecidea papillata*, relatively rare in *d*² and *d*³, but abundant in *d*¹.

*d*². Coarse-grained calcareous rock of a very pronounced greyish-brown colour, rough to the touch, somewhat brittle, stratified in regular beds, but in which the grey flints are rare. It is composed of a mixture of carbonate and phosphate of lime. This latter enters into the composition of very small brown grains, scarcely visible to the naked eye.

According to M. Peterman's analyses, this rock has the following composition †:—

Organic matter	2·83
Lime	53·24
Magnesia	0·12
Oxide of Iron and Alumina	1·01
Potash and Soda.....	0·19
Carbonic acid	28·10
Sulphuric acid	0·89
Phosphoric acid	11·66
Silica and Sand	1·96
Fluorine and Chlorine	traces

100·00

I would call attention to the large proportion of nitrogenized

* Most of the Cretaceous fossils of Cibly which are in the public collections of England and France were derived from the Conglomerate beds of Malogne.

† Bull. Acad. Royale de Belgique, 2^e sér. vol. xxxix.

organic matter which the Brown Phosphatic Chalk contains. It is to this substance that one must attribute the following fact, which has been pointed out by Professor Melsens of Brussels* :—

“The carbonic acid which is disengaged when the rock is treated with hydrochloric acid has a peculiar odour, reminding one of the smell of a marsh; when the disengagement of carbonic acid has ceased, and the acid liquid is heated, this marsh odour becomes stronger, and forcibly recalls the smell of the mud of ponds.”

In the subdivision d^2 a good many remains of Saurians and of Fish have been found, consisting chiefly of teeth and vertebræ, but the abundance of marine shells gives a very remarkable palæontological character to this deposit. A large number of specimens, such as the oysters, are found with their two valves united. The most common species are :—

Ditrupe Mosæ, *Bronn*, sp.
Belemnitella mucronata, *Schl.*, sp.
Baculites Faujasi, *Lamk.*
Pecten pulchellus, *Nils.*
 — *cretosus*, *Defr.*
 — *cicatrissatus*, *Goldf.*
Janira substriato-costata, *d'Orb.*
Lima semisulcata, *Goldf.*
Avicula cærulescens, *Nils.*
Ostrea santonensis?, *d'Orb.*
 — *lateralis*, *Nils.*
 — *larva*, *Lamk.*
 — *lunata*, *Lamk.*
 — *vesicularis*, *Lamk.*
 — *acutirostris*, *Nils.*
 — *curvirostris*, *Nils.*
 — *podopsidea*, *Nyst.*
Rhynchonella octoplicata, *Sow.*, sp.
 — *subplicata*, *d'Orb.*
 — *plicatilis*, *Sow.*

Terebratula semiglobosa, *Sow.*
 — *carnea*, *Sow.*
 — *Sowerbyi*, *Hagenow.*
Terebratulina striata, *Wahl.*, sp.
Terebrirostra Davidsoniana, *De Ryckh.*
 — *plicata*, *Bosquet.*
Terebratella Humboldti, *Hagenow.*
Argiope Davidsoni, *Bosquet.*
Trigonosemus elegans, *König.*
 — *Palissi*, *Woodw.*, sp.
Thecidea papillata, *Bronn.*
 — *recurvirostra*, *Defr.*
Crania Parisiensis, *Defr.*
 — *antiqua*, *Defr.*
 — *egnabergensis*, *Retzius.*
Requienia cipliyana, *De Ryck.*
Catopygus fenestratus, *Agass.*
Cardiaster ananchytis, *d'Orb.*
Cidaris Faujasi, *Desor.*

The thickness of the subdivision d^2 is from 20 to 30 feet.

d^3 . This subdivision is composed of a coarse phosphatic calcareous rock identical with that of the subdivision d^2 , but with numerous nodules of flint, isolated or arranged in continuous beds. This flint is brown in colour, often imperfect and with hollow spaces. It contains sometimes from 10 to 14 per cent. of phosphate of lime. The fossils are less common than in the bed d^2 , but they belong to the same species †. Besides, in d^3 numerous siliceous sponges are found.

These flints show by their texture that they also have had an organic origin.

* Bull. Acad. Royale de Belgique, 2^e sér. vol. xxxviii.

† In March 1885, the nearly entire skeleton of a Saurian, measuring with the tail 50 feet in length, was found at Mesvin in the beds of phosphatic and flinty chalk d^3 . This gigantic fossil now forms part of the collection of the Royal Museum of Natural History of Brussels. It has been described by M. Dollo, who has given it the name of *Hainosaurus Bernardi*.

The beds of d^3 have altogether a thickness of from 40 to 50 feet, but the proportion of phosphate of lime diminishes with the depth. Near the base the beds are almost entirely composed of carbonate of lime, alternating with phosphatic layers. We pass thus without sudden transition to the Chalk of Spiennes.

E. *Coarse Chalk of Spiennes*.—This is a coarse whitish chalk, rough to the touch, forming regular beds, and composed almost entirely of carbonate of lime. In it grey flint occurs abundantly, both in isolated nodules and in continuous and massive layers.

Fossils are somewhat rare in the Chalk of Spiennes. The principal are :—

Belemnitella mucronata, <i>Schl.</i> , sp.	Rhynchonella octoplicata, <i>Sow.</i> , sp.
Ostrea vesicularis, <i>Lamk.</i>	Echinocorys vulgaris, <i>Breyn.</i> , var. ovata.
Terebratula carnea, <i>Sow.</i>	

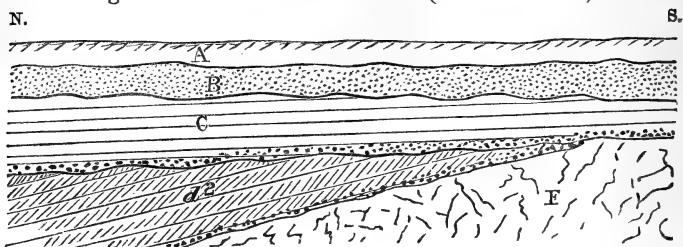
These are the species found everywhere in the Upper White Chalk of England, Germany, and France (Chalk of Meudon). They are found also in the White Chalk of Nouvelles which underlies the Chalk of Spiennes ; but in the latter, species appear which are only found in the Upper Cretaceous deposits. These are :—

Baculites Faujasi, <i>Lamk.</i>	Terebratula Sowerbyi, <i>Hagenow.</i>
Pecten pulchellus, <i>Nils.</i>	Trigonosemus Palissi, <i>Woodw.</i>
Lima semisulcata, <i>Goldf.</i>	Thecidea papillata, <i>Bronn.</i>
Avicula cærulescens, <i>Nils.</i>	Crania egnabergensis, <i>Retzius.</i>
Ostrea acutirostris, <i>Nils.</i>	Cardiaster ananchytis, <i>d'Orb.</i>
Rhynchonella subplicata, <i>d'Orb.</i>	

The greatest ascertained thickness of the Chalk of Spiennes exceeds 160 feet.

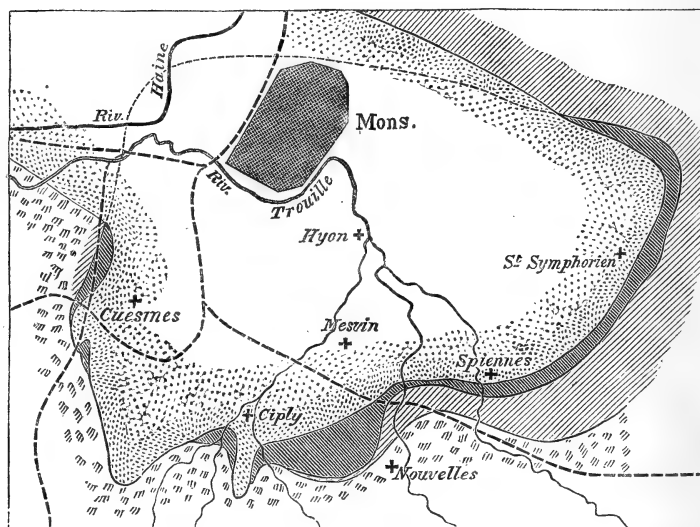
I am of opinion that the Brown Phosphatic Chalk of Cibly (D) and the Chalk of Spiennes (E) should be regarded as forming together one geological whole, a peculiar stage of the Belgian Cretaceous Series. This stage is here clearly defined by two surfaces of denudation. Before the deposition of the Chalk of Spiennes, the Chalk of Nouvelles had been deeply eroded by denudation. The same was the case with the Brown Phosphatic Chalk before the deposition of the Tufaceous Chalk of Cibly, but the two surfaces of denudation are not parallel. Hence it results that the superposition of the beds seen at Cibly and at Mesvin, as represented in fig. 2, does not exist everywhere on the line of outcrop of the phosphatic beds. It is only in the workings at Mesvin that the upper beds d^1 have been found. To the east of this locality the Tufaceous Chalk (*Tufeau*) lies upon the subdivision d^2 or on d^3 . Westward the two surfaces of denudation come near to each other, near enough to account for the disappearance of the Chalk of Spiennes, of all or a great part of the beds d^3 , and of all the beds d^1 . In this last instance the superposition is indicated by fig. 3.






Fig. 3.—Section near Cuesmes. (Scale 1 : 1000.)



- A. Quaternary strata.
 B. Tertiary strata. Landenian system.
 C. Tufaceous Chalk of Ciply, with conglomerate at the base.
 d². Brown Phosphatic Chalk with conglomerate at the base.
 F. White Chalk of Nouvelles.

Fig. 4.—Geological Sketch Map, showing the Extension of the Phosphatic Chalk of Ciply, near Mons, in Belgium.
 (Scale 1 : 100,000.)



- | | | | |
|---|----------------------------|---|---------------------------|
|  | Tufaceous Chalk of Ciply. |  | Chalk of Spiennes. |
|  | Phosphatic Chalk of Ciply. |  | White Chalk of Nouvelles. |
|  | | Railway. | |

The Tufaceous Chalk (C) passes transgressively over the Chalk of Nouvelles (F), which directly underlies the brown phosphatic chalk *d*². A conglomerate (*Poudingue de la Malogne*) appears under the Tufaceous Chalk, but another analogous deposit, to which M. Briart and I have given the name of Conglomerate of Cuesmes, is seen on the denuded surface of the Chalk of Nouvelles. This conglomerate, of which the thickness varies from a few inches to several feet, is composed of brown nodules, so rich in phosphate of lime that it sometimes exceeds 45 per cent. A great number of these nodules are the interior casts of fossil shells.

The above description will suffice to give a correct idea of the extent and importance of the beds of phosphatic chalk in the neighbourhood of Mons. To enable the reader to appreciate their importance from their superficial area, the map (fig. 4) is here given. It is a geological map, drawn to the scale of 1:100,000, and in which the Tertiary deposits are not represented. The phosphatic beds are spread out in an elliptical basin, the greater axis of which is in a direction from south-west to north-east and measures 5 English miles. The length of its smaller axis probably exceeds 3 miles; nothing can, however, be affirmed with certainty on this point, as the northern limit of the phosphatic deposit is not yet well known. But its southern boundary has been traced as clearly as possible, as laid down on the map; it measures 8 miles in length. It is along this southern limit that the phosphate workings are now carried on.

Up to the present time, the workings at Cuesmes, Ciply, and Mesvin have only been carried to the surface of the underground water-level, which is found everywhere at a certain depth in the Cretaceous strata in the neighbourhood of Mons. The Brown Phosphatic Chalk has there the greyish-brown tint of which I have already spoken; but towards the eastern extremity of the phosphatic basin, between St. Symphorien and Havré, the workings are carried on below the underground water-level. The Brown Phosphatic Chalk there exhibits a colour strikingly different from that of Cuesmes, Ciply, and Mesvin. It is of a very dark bluish green, and might from its appearance at first sight be confounded with certain glauconiferous chalks occurring in several geological stages of the neighbourhood of Mons. Nevertheless, as regards its chemical composition, the phosphatic chalk of St. Symphorien and Havré does not differ materially from that which is worked more to the westward. The difference of colour seems to be due to different degrees of oxidization of the small quantity of iron contained in the rock.

The oldest workings of phosphate of lime in the neighbourhood of Mons were begun in 1872; but, having only for their object the extraction and treatment of the nodules of the conglomerate of Malogne, they were soon abandoned.

It was in 1874 that the first quarry was opened at Ciply for the working of the Brown Phosphatic Chalk of the subdivision d^2 . The analysis of this chalk already given shows that it is too poor in phosphate and too rich in carbonate of lime to be treated by sulphuric acid in the manufacture of superphosphate. But by simple mechanical processes, either by dry or wet methods, a product is obtained which contains from 40 to 50 per cent. of phosphate. If these processes are preceded by calcination of the chalk and hydration of the lime thus produced, a phosphate is obtained of from 50 to 60 per cent. Some experiments now being made lead us to hope that a proportion of 65 per cent. may be reached.

The industrial means employed for enriching the brown phosphatic chalk consist in reducing the proportion of carbonate of lime which is contained in the rock. These processes are only an imitation of what has taken place naturally at certain points of the outcrop of the phosphatic beds. By the action of a solvent, which was probably surface-water charged with carbonic acid, the brown chalk has lost the greater part of the lime which it contained in the state of carbonate, and has been transformed into a substance known under the name of *rich phosphate*.

The rich phosphate is only found in those places where the brown chalk of the subdivisions d^2 and d^3 comes in contact with the post-Cretaceous beds. It never occurs when the beds present the superposition indicated in fig. 3, that is to say when the Tufaceous Chalk entirely covers the Brown Chalk, but it is met with almost always where the stratification is as shown in fig. 2.

The rich phosphate occurs under two different physical conditions, according as it is found above or below the level of the underground water. In the first case, which is that of the actual workings at Cuesmes, Mesvin, Ciply, Nouvelles, and a part of St. Symphorien, it presents itself in the form of a powdery substance of a bright yellow or reddish-yellow colour, much resembling certain very fine ferruginous sands. The richness of this substance in phosphate of lime varies from 45 to 67 per cent. The following is the composition of an average specimen from Mesvin, given by Dr. Peterman* (the material has probably been dried):—

Organic matter	5.21
Oxide of Iron and Alumina	3.96
Lime	41.72
Magnesia.....	0.84
Potash	1.00
Soda.....	1.13
Phosphoric acid	27.79
Sulphuric acid.....	1.18
Carbonic acid	5.06
Insoluble matter (Silica, Sand).....	10.68
Chlorine	traces
Fluorine and loss	1.43
	100.00

* Bull. de l'Acad. Royale de Belgique, 3^e sér. vol. i.

Between the villages of St. Symphorien and Havré the rich phosphate is met with below the level of the underground water. The substance here has a greenish-blue tint, very different from that of the rich phosphate of Mesvin, Ciply, &c. Its chemical composition has been determined as follows by Professor Blas of Louvain* :—

Dried substance preserved in the air of the laboratory.

1. Water at 115° C.	0.60
2. Organic matter	2.67
3. Iron oxide	2.07
4. Alumina	1.72
5. Lime	38.52
6. Magnesia	0.40
7. Potash	0.03
8. Soda	1.47
9. Phosphoric acid.....	25.85
10. Sulphuric acid	4.05
11. Carbonic acid.....	5.40
12. Silica	14.00
13. Chlorine.....	0.15
14. Fluorine	2.38
15. Impurities in the Silica	0.60
	<hr/>
Deduct:—	99.91
For an equivalent of fluorine and an equivalent of oxygen	1.00
For an equivalent of chlorine.....	0.03
	<hr/>
	1.03
	<hr/>
Balance.....	98.88
Manganese and other bodies not determined	1.12
	<hr/>
	100.00

M. Blas found traces of iodine in the residue.

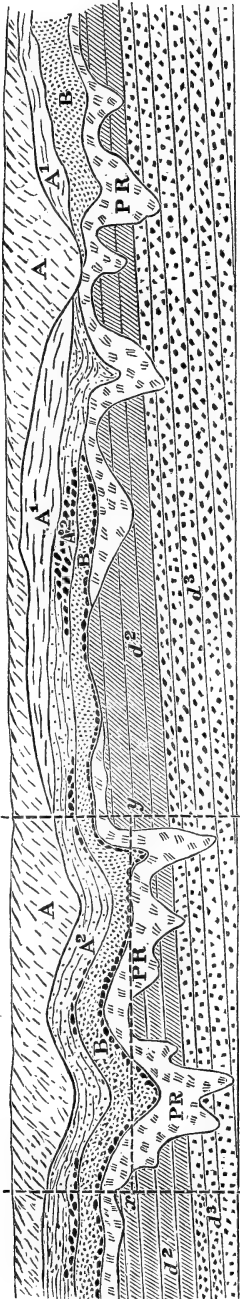
According to the two analyses which I have just given, there are notable differences between the rich reddish-yellow phosphate of Mesvin and the rich greenish-blue phosphate of Havré. The latter contains less organic matter than the former, but more insoluble substances and more fluorine. These differences are probably due to various causes, which I will not enter upon here. I will only remark that the rich phosphate of Mesvin, analyzed by M. Peterman, was derived from a deposit resting upon the brown chalk without flints, *d*²; whilst that at Havré, the rich phosphate of which M. Blas has given the composition, was superimposed upon the brown chalk with flints, *d*³.

The extraction of the rich phosphate was commenced in 1879, on the land of the Commune of Mesvin. Since then the workings have been successively extended to Ciply, St. Symphorien, Havré, Nouvelles, and Cuesmes, that is to say nearly everywhere that the Brown Phosphatic Chalk is not covered by the Tufaceous Chalk.

It is at Mesvin, Ciply, and Cuesmes that the beds most remarkable for their thickness have been found. Fig. 5 gives the exact repre-

* Bull. de l'Acad. Royale de Belgique, 3^e sér. vol. viii.

Fig. 5.—Vertical Section of a Quarry near Mesvin. (Scale 1 : 500.)



sentation of an open quarry at Mesvin; and fig. 6 represents the horizontal section of the portion indicated by the line *xy*.

The following is the description of this quarry:—

- A. The upper part is vegetable soil, mixed with humus and very fertile. Below it is a reddish-brown loam, without lime, well adapted for the manufacture of bricks. Occasionally small fragments of flint are met with.
- A¹. Yellow calcareous loam, sometimes very distinctly stratified, and often containing small rounded grains of white chalk. It is this deposit which Belgian geologists designate by the name of *Ergeron*. Occasionally, and in some abundance, the following shells are found:—

Helix hispida.
Pupa muscorum.
Succinea oblonga.

These three species still live in the locality, but the living shells are of much larger dimensions than the fossil.

- A². Stratified beds of sandy loam, sand, and small rolled fragments of flint and of white chalk, resting on a pebbly mass composed chiefly of débris of rather large and subangular flints, mixed with fragments of various Tertiary and Devonian rocks. There have been found in this deposit, generally in the lower part, numerous bones of Mammoth, Rhinoceros, Ox, Horse, &c., with flints worked by man. I myself have found many, amongst which are several specimens of a more perfect form than any of the remains of human industry hitherto discovered in the Quaternary alluvium.

The beds A¹ and A² are not continuous, but in one or other in the Mesvin quarry numerous breaks occur. The brick-earth A often rests upon A², and even on B.

B. Lower stage of the Landenian system, consisting of grains of quartz and glauconite cemented by a more or less abundant argillaceous matrix. Underneath there is a bed containing black flint pebbles and nodules derived from the Chalk.

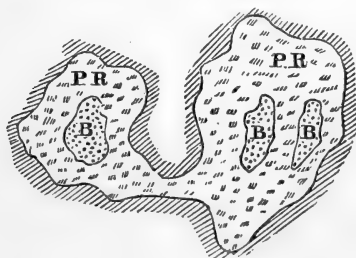
The natural colour of stage B is dark greenish-blue, but at many places it has acquired a yellowish ferruginous tint, in consequence of the alteration of the glauconite.

d². Brown phosphatic chalk without flints, containing many fossil shells, the shells consisting of carbonate of lime.

d³. Brown phosphatic chalk with flint nodules, scattered or arranged in continuous layers. Also numerous fossils with the shells of carbonate of lime, and sponges changed into flint.

PR. A yellow-brown, powdery rich phosphate; its chemical composition given above. It fills pockets, whose walls, formed by the brown phosphatic chalk, are sharp, clean, and without any transition between the two substances in contact. Fossil shells, such as the *Belemnitella* and Oysters, are often cut through by the line of separation, and only the portions of those shells that are imbedded in the chalk are preserved; the parts which should have been prolonged into the rich phosphate do not exist. The fossil remains found in it are only siliceous sponges, teeth and vertebræ of Sharks and of Saurians, *Hainosaurus*, *Mosasaurus*, &c. Nodules of flint also occur, similar to those found in the Chalk d³.

Fig. 6.—Horizontal Section in the plane indicated by the line x-y in Fig. 5. (Scale 1 : 500.)



The pockets represented in figs. 5 and 6 were from 40 to 50 feet in maximum diameter, and from 20 to 25 feet in depth; but some have been discovered of much larger dimensions. Several of them have furnished nearly 2000 tons of rich phosphate.

It seems evident to the author of this paper, and it is likewise the opinion of all the geologists who have studied the deposits just

described, that the rich phosphate is the residue of a chemical alteration undergone by the Brown Phosphatic Chalk after its deposition. This alteration has caused the fossil shells preserved as carbonate of lime to disappear, together with the greater part of the carbonate of lime originally contained in the rock. It has not affected the flints or the siliceous sponges, or the bones of vertebrate animals, in the composition of which there is a large proportion of phosphate of lime.

The agent which has dissolved the carbonate of lime could only have been water charged with carbonic acid. Any other acid would at the same time have acted on the phosphate as well as on the carbonate.

The water, rendered corrosive by carbonic acid, has not come from the interior of the earth, that is to say it is not water from springs; for if such had been the case, it would have first attacked the beds of White Chalk which underlie the Brown Phosphatic Chalk. One would only find the cavities produced by its action, and the pockets of rich phosphate would be found not only at the places where the Brown Phosphatic Chalk underlies the Tertiary or Quaternary deposits, but also where it is covered by the Tufaceous Chalk. But up to the present time nothing of this sort has been found to exist, notwithstanding the extent of the works in the neighbourhood of Mons. A few pockets have been discovered under the Tufaceous Chalk, but only where it was from two to three feet thick. In this last instance, the Tufaceous Chalk was traversed by a pocket of which the upper part was always found filled with Tertiary or Quaternary deposits. Sometimes also pockets of rich phosphate have been worked in the White Chalk, but it has also always been proved that they were only the prolongation in depth of those which traversed the Brown Phosphatic Chalk. The dissolving action had not been arrested at the base of this latter, but it had penetrated into the White Chalk, which is composed of nearly pure carbonate of lime.

Since the water charged with carbonic acid has not risen from below, it could only have come from above. We must look to the atmosphere for its source.

The study of the phosphatic beds of the neighbourhood of Mons raises many scientific questions of the highest interest; but I shall not now attempt to discuss them. I shall confine myself to saying a few words on one point only.

At those places where the succession of the beds of phosphatic chalk, d^2 and d^3 , is complete, the total thickness is from 60 to 85 feet. This would give an average of 70 feet.

The specific gravity of the phosphatic chalk, drained of the quarry water, is 1.55. A cubic foot of this rock weighs therefore 31 lb. 12 oz. We may therefore take as a mean minimum a proportion of tribasic phosphate of lime of 18 per cent. One cubic foot therefore would contain 5 lb. 11 oz., and 70 cubic feet 355 lb.; that is to say, that for every square foot measured on the surface of

the phosphatic deposit, taken at its mean depth of 70 feet, there exists a quantity of tribasic phosphate of lime equal to that contained in the bodies of 80 living human beings*.

To what cause can the deposit of so prodigious a quantity of phosphate of lime be attributed?

Three points are indisputable:—

1. The phosphate contained in the brown chalk of Cibly is of animal origin, as is proved by the large proportion of nitrogenized organic matter contained in it.

2. It was deposited in a sea that nourished a numerous fauna of shells, and in which existed fish and great marine Saurians.

3. Its deposition was effected tranquilly, as is proved by the great regularity of the beds, and by the condition of the fossil shells, which have often their two valves united.

So far as I know, there has been no discovery, up to the present time, in other parts of the globe, of phosphatic beds analogous to those of the environs of Mons; but there exists in nature a fact which may perhaps explain the formation of the beds of the brown chalk of Cibly. In the 'New Universal Geography,' by Elisée Reclus, the following statement occurs †:—

"At the period of change of the monsoon, chiefly in October and November, millions of all kinds of dead fish are thrown up by the sea on the coasts of Perim and of Aden. In order that the air should not be tainted, the inhabitants set to work to bury this mass of putrefied flesh. What is the cause of this mortality among the fish? The natives attribute it to some poisonous substance, whilst King ascribes it to electrical phenomena caused by the change of the season ‡. The myriads of organisms which perish under the incessantly renewed layers of successive organisms, suffice in many localities to feed springs of the oily materials, which ooze out upon the seashore" §.

The cause that leads to the mortality of the animals inhabiting the waters of the Gulf of Aden does not, however, concern the question before us. The important fact is, that at certain seasons of the year, *i. e.* periodically, there is an accumulation, on certain parts of the southern coast of the Peninsula of Arabia, of animal substances very rich in tribasic phosphate of lime. There is no reason why we should not admit that the same phenomenon may have been in action at different periods of geological time. One may therefore ask, whether it was not to a similar action, coincident perhaps with a slow depression of the coast, that the formation of the Brown Phosphatic Chalk of Cibly may be attributed.

DISCUSSION.

The PRESIDENT said that two important considerations arose from this paper:—(1) that these beds were amongst the very highest in

* See on this subject the calculations of M. Melsens, 'Bulletin de l'Académie Royale de Belgique,' 2^e sér. vol. xxxviii. p. 40.

† Vol. ix. pp. 869, 870.

‡ 'Geographical Magazine,' 1877.

§ Oscar Fraas, 'Aus dem Orient.'

the Chalk ; (2) the interesting facts as to the possible formation of the phosphates.

Prof. PRESTWICH remarked on the great interest of the paper, both palæontologically and mineralogically. In the Paris basin and in England the Chalk stops with the Senonian ; but here we have a deposit which lies between the equivalents of the Maestricht Chalk and the Senonian : he considered the evidence of its distinctive character very satisfactory.

In this country a few of the lower beds of the Chalk contain phosphates, but they are of little importance.

It was remarkable that the deposit should be confined to so small a district. It was singular also that in the neighbourhood of Mons not only should the Cretaceous series be more complete than anywhere else, but also the Lower Tertiary series. Even the Quaternary beds show the same completeness.

He considered the explanation as to the origin of the phosphates interesting, and alluded to the beds of phosphate of lime at Quercy.

Mr. BAUERMAN congratulated the Society on the valuable paper they had heard from their distinguished Belgian correspondent, whose example he hoped would stimulate contributions from other foreign Members. He observed that there was very little to criticize. He was disposed to agree with the Author's explanation as regards origin—an instance of differential separation in weak acidulous waters ; he quoted an analogous case in the Devonian limestones of the Lahn valley, and the formation of staffelite. He further instanced the deposits of Leadville, in which the less soluble substances had been deposited as carbonates in the hollows of limestones below.

Dr. DUNCAN admired the fossils, and observed that the species of *Catopygus* approximates more to the recent forms than does the one from the Lower Chalk.

Mr. BLANFORD thought there might be some mistake as to the quotation with reference to Perim and Aden, and suggested that the locality where the periodical destruction of fish-life occurred was the Malabar coast.

Dr. HICKS had observed in Cambrian and Silurian beds an increase of phosphates corresponding to an increase in animal remains. He thought some of the results might be due to secondary causes.

Dr. WOODWARD thought that possibly the phosphate in the Brown Chalk of Cibly might not have been of contemporaneous origin, but derived in some way from Tertiary beds above.

Mr. HUDLESTON pointed out that this latter suggestion was scarcely justified by the facts, since the Phosphatic Chalk was protected by the Tufaceous Chalk. He referred to the abundant remains of fish and saurians in the bed as indicating, in part at least, the source of the phosphate.

The PRESIDENT, in conclusion, said the thanks of the Society were due to Mrs. Prestwich for her excellent translation of the paper.

28. *On a certain FOSSILIFEROUS PEBBLE-BAND in the "OLIVE GROUP of the EASTERN SALT RANGE, PUNJAB.* By A. B. WYNNE, Esq., F.G.S. (Read April 21, 1886.)

Not long ago I received from my friend Dr. H. K. Warth some very interesting specimens, including fossil *Conulariæ*, discovered by him in the Eastern Salt Range, parts of which region I had examined from his bungalow at the Mayo Salt-mines, and sometimes in his company. His discovery was the subject of a short paper by myself read before the Royal Geological Society of Ireland, an abstract of which appeared in the 'Geological Magazine' for March 1886.

Almost immediately afterwards, the Records of the Geological Survey of India (vol. xix. pt. 1, 1886) having reached me, I found therein a paper on the same subject by Dr. Waagen, of Prague. The treatment of the matter in this paper and the extent to which its deductions are carried with regard to the geology of the whole Eastern Hemisphere are too important in their bearing upon Salt-Range geology and stratigraphy to be quite passed over by an individual who had the largest part of the task of examining that Range for the Geological Survey of India.

So far as the paper now referred to deals with the stratigraphy of the Range, I am in a position to offer opinions the result of direct observation; where it deals with purely palæontological matter, I offer none; and where it embraces collateral questions, bearing upon the geology of half the earth, depending upon stratigraphic features of the Range, I claim recognition of the observed facts only so far as my own part in these observations is involved, or where these are supported by the independent views of others.

The fossils discovered by Dr. Warth about a year ago in a locally upper, or the uppermost thin layer of a certain Boulder-bed with glaciated blocks, in the "Olive Group" of the Salt-Range series, have been determined by Dr. Waagen to comprise ten Palæozoic species, which he finally (so far) decides to belong to the Carboniferous period*. The age of this "Olive Group" having been previously fixed by Dr. Waagen and myself as probably Cretaceous †, anything tending to throw additional light in that direction would

* See my Salt-Range Report, Mem. Geol. Surv. Ind. vol. xiv. p. 67 &c.

† The fossils from this group described by Dr. Waagen are:—

- | | |
|---|--|
| 1. <i>Conularia lævigata</i> , <i>Morris</i> . | 6. <i>Atomodesma</i> (?), <i>Waagen</i> . |
| 2. — <i>tenuistriata</i> , <i>M'Coy</i> . | 7. <i>Aviculopecten</i> , cf. <i>limæformis</i> ,
<i>Morris</i> . |
| 3. — <i>irregularis</i> , <i>de Koninck</i> . | 8. <i>Discina</i> , sp. indet. |
| 4. <i>Bucania</i> , cf. <i>kattaensis</i> , <i>Waagen</i> . | 9. <i>Serpulites Warthi</i> , n. sp., <i>Waagen</i> . |
| 5. <i>Nucula</i> , sp. indet. | 10. — <i>tuba</i> , n. sp., <i>Waagen</i> . |

All except the fourth are figured in Dr. Waagen's plate, and all except the first two are given by him as either new species or doubtful, that is to say requiring further comparison.

be valuable. We had no doubt that part of the group, but not at this locality, contained *Terebratula Flemingi*, Davidson, and to this Dr. Waagen now adds *Cardita Beaumonti*, another Cretaceous form, while Dr. Warth informs me he has recently obtained, at its uppermost limits, "Turtle, 3 feet in length," fish-teeth ("*Lamna*, sp., *Otodus*, sp., *Hemipristis*, sp., *Capitodus*, sp."), "*Belemnites* and shells." Both Dr. T. Oldham and myself had previously observed fossils at this horizon in the eastern part of the Range, but they were difficult to extract and, so far as I know, have never been determined. I found them at coal-localities in the neighbourhood of Pid, and to the westward in yellowish fine-grained siliceous and slightly ferruginous beds, of blue colour internally.

The nearest horizon below the "Olive Group" (in the eastern part) of the Salt Range from which fossils had previously been procured was amongst the "Magnesian Sandstone" beds of Chel Hill, a narrow ridge faulted on both sides. I have doubtfully suggested that the beds containing these fossils may be in the lower part of the group*, but I had ascended the flank of the hill for some distance before I found them. Here in some dark chunchy shales and flags, associated with soft micaceous, dark and pale grey, and dull reddish sandstones, I obtained a few small and indefinite plant-fragments, and small broken sharks' teeth, together with a larger tooth, since described with qualifying remarks as *Sigmodus dubius*, Waag., n. sp. †. There may be considerable doubt as to the exact place of these fossils in the group succeeding the "*Obolus*-beds," which were formerly fixed by Drs. Oldham and Stoliczka as not newer than Silurian ‡.

This was the state of things when Dr. Warth's discovery of a *Conularia*-containing layer was made, and his fossils were forwarded to Europe to Dr. Waagen, who now refers them to the Carboniferous period §, a determination which it is entirely beyond my object to discuss; but Dr. Waagen and Mr. Medlicott both state || that these lately found fossils occur in concretions, *in situ*, chiefly, it would seem, on other grounds than their own observation.

* Salt-Range Report, Mem. G. S. Ind. vol. xiv. p. 145.

† Pal. Ind. ser. xiii. l. i. pp. 9, 11.

‡ As two or more thick groups of rocks intervene between the *Sigmodus*-layers and the *Conularia*-band, it is much to be regretted that the locality was not more closely explored. At the time the prospect of finding fossils in these beds was not so hopeless as it afterwards proved. All that I obtained were from the same spot and almost the same bed; the material generally became friable when kept, and the remains were so difficult to preserve that when I saw them again after a long interval in Calcutta, most of those collected had disappeared. Should further exploration of Chel Hill be made, I should not feel surprised to learn that the dark-coloured beds with these fossils are really nearer the upper portion of the group than I supposed. The ridge is not very far from the area within which Dr. Warth's discovery was made, and the "Olive-bed" conglomerates, with their metamorphic boulders in an almost trappian mud-like base, are present along its south-eastern flank.

§ Rec. G. S. Ind. vol. xix. pt. 1. pp. 2, 29.

|| *Loc. cit.* pp. 2, 29.

In opposition to his first-formed conviction to the contrary, Dr. Waagen advances, only :—

1. That the (so-called) concretions occur regularly and plentifully in a thin layer at the top of, and not throughout, a whole thick boulder-bed.
2. That the thin layer has a regular constant horizontal distribution over more than ten square miles.
3. That its fauna is a very uniform one, pointing distinctly to a single geological horizon, no mixture of foreign forms occurring, as a presumed necessary result if the fossils were not *in situ*.

I cannot pretend to any precise recollection of this particular thin layer at the top of the Olive-group Boulder-beds, though the pebbles from it sent me by Dr. Warth seem familiar. Both concretionary and conglomeratic beds are common enough in the neighbourhood, and it would not serve any useful end were I to attempt to draw the exact line between a memory and what can be so easily imagined*. But I have ample evidence of a better kind to contrast with Dr. Waagen's view, and with the three reasons he has given as above condensed. Dr. Warth, who has doubtless most carefully considered all the appearances presented by the layer and its contents, favours me with conclusions arrived at on the spot. Under the date December 1st, 1885, at a time when these pebbles had been already spoken of as concretions, he wrote from Pid, Eastern Salt Range, thus :—“ From Choah-Saidun-Shah to Makrach I have found the thin conglomerate bank, with the pebbles which enclose *Conularias* and two or three other shells, absolutely uninterrupted in the ‘Olive Series’ (upper portion). I send you a single *Conularia* which was found in a rounded-off state in the conglomerate. It is evident that the *Conulariæ* have not become fossils on the spot, but have been brought from a distant mountain as pebbles; but how these were distributed over such a large area in such a thin layer is very extraordinary” †.

The single specimen here referred to has a label in Dr. Warth's writing saying he took it “ in its present state from the face of the bed.” It is now in the geological collection of Trinity College, Dublin, and no one who inspects it can doubt the accuracy of Dr. Warth's view that this rolled fossil was not *in situ* in the position in which he found it. In the same packet I found another rolled *Conularia*, so much abraded that scarcely anything remains except the general indication of its tapering form and rhomboidal section. Nor did the other specimens sent containing *Conulariæ*

* I have looked over some of my old field-notes of February 1870, and they only confirm the opinions I have always held as to the inter-relations of the Eastern Salt-Range groups.

† From the map I constructed in the field, this area may have been 5 miles by 2 in its general form, or rather longer and more narrow, but it is not more closely defined by Dr. Warth than in the quotation.

prove to be concretions. Their material is a fine-grained grey and rusty, non-calcareous sandstone, exhibiting no concretionary structure; their rolled and abraded surfaces intersect the contained fossils, and even if the pebbles have ever been nodules their surfaces show that they have been rolled and transported before being enclosed in Dr. Warth's conglomerate bank.

This being so, the Carboniferous age of the fossils would tend to show that the *Conularia*-layer is newer than the fossils themselves, and the whole of the correlations depending upon the point, whether regarding the boulder-beds of the East or West Salt Range, or the relations of these to other boulder-beds at great distances, must lose in value or disappear. And yet, though there is no proof, the fact may exist, that the rocks immediately beneath the chief boulder-deposits of the eastern part of the Salt Range are of at least Palæozoic if not of Upper Carboniferous age*.

The group next below this red zone is a mass of light-coloured sandstones, often magnesian, with no great variety of texture, generally very hard, occasionally oolitic, sometimes alternating with greenish or grey shaly partings, and but rarely and feebly conglomeratic, as they extend westward. Its hardness has caused the group to assume the most prominent position among the cliffs of the eastern part of the range. Superficially the beds present here and there the indefinite markings often described as *Annelidan* or *Fucoidal*; but in these pale beds I never found a determinable fossil, while of the few from intercalated dark, sandy, shaly layers, possibly but very doubtfully situated near their base, or in their lower part, at Chel Hill (previously referred to), the single unsatisfactorily determined species (*Sigmodus dubius*, Waagen) has not been assigned to any definite place in the Palæozoic period, this being assumed by Dr. Waagen to be the undoubted general age of the deposits from which it came (Pal. Ind. ser. xiii. l. i. Pisces: Cephalopoda, p. 9).

Except the few forms amongst which this fossil was found, no other organic evidence has yet been afforded by any of the beds lying between the "*Obolus*-band" and the "*Conularia*-layer;" and the relative grouping was only decided upon by tracing the "*Obolus*-beds" and the "Magnesian sandstone" (with less distinct character) passing westwards beneath certain "speckled sandstones" which underlie the Carboniferous Limestone, &c.

* One portion of these underlying rocks, the red sandy and earthy zone full of pseudomorphic casts of salt-crystals, is now claimed by Dr. Waagen as Carboniferous. It was at his suggestion alone that any attempt was made to define its nominal age in my report, and the period he suggested was Triassic, a point quite unnoticed in his present paper.

The recent inspection of this part of the Salt-Range series by Mr. R. Oldham of the Indian Survey (Record Geol. Surv. Ind. vol. xix. pt. 2, p. 127) confirms the views I had held, and has further resulted in the opinion that the "Olive group" rests unconformably upon these red rocks with pseudomorphic salt-crystals. The unconformity so indicated might have a most important effect in the lateral limitation of the Eastern Salt-Range boulder-beds.

The stratigraphic relations of the Salt-Range series having been treated of from a non-palæontological position, depending upon the distribution of its so-called glacial boulder-beds, the consideration of the facts regarding these renders it necessary to present a condensed diagrammatic idea of the distribution of the whole of the rock-groups as they occur in different cross-sections of the range. This is done in the annexed table (p. 346), the groups being numbered to show their relative general stratigraphic positions in the local series as realized from close observations constantly compared.

The argument of Dr. Waagen's paper in the Indian Records is that all the boulder-beds lying between Nos. 8 & 11 in the eastern columns of the table, and those lying between Nos. 1 or 2 and 6 in the western columns, pertain to one general group of rocks of glacial character, and belonging to the upper portion of the Carboniferous series; that they are discordant, both to the underlying saline series and to the overlying Mesozoic groups*; and are identical or homotaxial with the Talchir boulder-beds of the peninsular Gondwana series, and also with certain glacial boulder-beds in Australia and South Africa.

These peculiar boulder-beds of the Salt Range, at an early period of their observation, suggested a similarity between themselves and the Talchir deposits of Central India; but the first evidence of their boulders bearing glacial markings was discovered by Mr. Theobald after the east part of the Salt Range had been mapped†. Like all the natural groups of the range, they presented definite features and inconstant horizontal distribution; in addition, they were often found to present general similarity of character, particularly as to their crystalline contents, with slight variation from purple to very dark tints of their earthy matrix. Their chief peculiarity, however, is that their metamorphic blocks are absolutely foreign to the whole neighbouring countries, so far as could be ascertained‡ while the ground was under examination. The boulder-beds prevail most collectively in two areas, one in the eastern part, and another larger development far away in the western part of the cis-Indus Salt Range and its extension trans-Indus in that direction. As stated in my Report on the Salt Range, p. 278, these beds were found to occupy different horizons, and being united by their crystalline blocks with a very considerable conglomeratic band, from just above the Eocene limestone downwards to the basal saline group of the series, their glacial character becomes an accessory of, rather than a special cause for, their existence. Under the tranquil

* Notwithstanding Dr. Waagen's previous statement that total unconformity is "absolutely wanting in the Salt-Range," Pal. Ind. ser. xiii. Salt-Range Foss. pt. i. p. 2, foot.

† I learn for the first time, from this paper by Dr. Waagen, that he observed a great number of striated pebbles in these beds, although our conferences were continual and, on my part, without reserve.

‡ On this point Mr. Oldham's late visit to the Salt Range has enabled him to identify among the fragments several varieties of well-known peninsular rocks, an important and satisfactory addition to previous knowledge. See his paper, *loc. cit. supra*.

Salt-Range Series in different regions of the Range and its extension trans-Indus.

WEST.

EAST.

TRANS-INDUS SECTIONS.	WESTERN SALT-RANGE SECTIONS.	INTERMEDIATE SECTIONS.	EASTERN SALT-RANGE SECTIONS.
12. { Tertiary sandstones, conglomerates, and clays.	12. { Tertiary sandstones, conglomerates, and clays.	12. Tertiary sandstones, &c.	12. { Tertiary sandstones and clays, conglomerates and boulder-beds.
11. { Olive clays, pale sandstone, pale limestones (Nummulitic), thick in places.	11. { Nummulitic limestone, coaly zone in places, not at base, but further up in the formation.	11. { Nummulitic limestone, coaly zone at base.	11. { Nummulitic limestone, coaly zone at its base.
10. { Whitish sandstones over a dark earthy zone containing Cretaceous fossils (Waagen).	10. { Pale sandstones, Cretaceous?	{ Sandstones thinner than to east.	{ Sandstones, &c., with <i>Cardita Beaumonti</i> (Waagen, auth.).
9. { Thin limestones over variegated beds, Jurassic.	{ Variegated Jurassic Sandstones, shales, &c.; <i>Belonites</i> , &c.; plants (ferns, Fleming).	10. { Olivestones and boulder-beds dying out to west, beds more shaly than to east, <i>Terebratula Flemingi</i> , Dav.	10. { Olive sandstone with CONULARIA PEBBLE-LAYER, above dark glacial (?) Boulder-beds.
7. { Ceratite shales, &c., Triassic. Grey and white limestones, full of Carboniferous fossils (upper part Permian, <i>vide</i> Waagen).	7. { Ceratite shales, &c., Triassic. Thick limestones, sandstones, and shales, full of Carboniferous fossils (upper part Permian of Waagen).	6. { Thin impure limestone, Carboniferous, <i>Fusulina</i> , &c., <i>Producta</i> , &c.	8. { Red salt pseudomorph zone, with lenticular conglomerates, and much red clay.
5. { Boulder-beds greatly developed, with gypsum and dolomite.	5. { Lavender clays over speckled sandstone and red shales, Boulder-beds.	5. { Speckled sandstones, increasing westward.	4. { Magnesian sandstones, greyish shales, passing under No. 5.
2. { Purple sandstones.	2. { Purple sandstones, locally absent.	3. { <i>Obolus</i> -zone, dying out to west.	3. { Dark clunchy <i>Obolus</i> -zone, Silurian (Stoliczka & Oldham).
1. { Salt-marl, &c., only at the Indus certain. Mostly absent or concealed.	1. { Salt-marl, salt, and gypsum.	1. { Salt-marls, salt, and gypsum.	1. { Salt-marl, salt, and gypsum.
		2. { Purple sandstones.	2. { Purple sandstone, thick.

conditions which so largely mark the accumulation of the whole Salt-Range series, and with the horizontally limited distribution of so many of its characteristic members, the recurrence of similar mechanically formed beds at different vertical stages presents no improbability, indeed would seem more likely to occur than very abrupt changes.

It would be difficult to suppose conditions of glaciation in any way limited to the areas of chief development of these boulder-beds; but it would be still more difficult to recognize, either in their contents or their distribution, such evidence that their largest developments were contemporaneous as would outweigh their relations of position, respectively and severally united with the uppermost and lowest rocks of the series, at different parts of the range. Even if the most elastic use be made of the word contemporaneous, the deduction to follow the identification of the eastern with the western boulder-beds would be, that almost the whole Salt-Range series was of a certain glacial age, overriding all other chronological indications; or if these last were to any extent admitted, the glacial period would have to be extended through enormous intervals of geological time in order to include the whole of the boulder-beds and their related deposits. The evidence afforded by a few rounded and striated boulders in isolated deposits at different vertical positions in a series is hardly capable of such an interpretation as would result from its application to the full extent suggested or advocated in Dr. Waagen's paper. In the trans-Indus area some idea of the place of the boulder-beds is to be obtained from the presence beneath them of such purple sandstones as form the great group of that name, to the east, immediately overlying the salt-marl; but among the earthy masses full of boulders, I found it hard to fix upon any blocks exhibiting distinct glacial striation; and the alternation with gypseous and sandstone beds is so frequent that the whole group might well contain equivalents of other absent characteristic members, before it is succeeded, with the usual conformity, by the Carboniferous *Productus*-limestones, &c.

Where the Indus crosses the range, the boulder-beds are much less prominent; but here the greatest obscurity prevails from landslips and faulting, with, it may be, limited deposition or even unconformity, insufficiently proved.

Further east in the Salt Range proper, about Swas, and towards the south-east as far as Amb and the neighbourhood of Sakésir Peak, boulder-deposits occasionally reappear just above the "Purple Sandstone," or taking the place of either its basal or upper parts—sometimes appearing to be closely connected with the "Salt-Marl," and sometimes in, or under, the "Speckled Sandstone," where this is present.

Following these boulder-beds still further eastward, their last representative recognized in that direction was immediately overlain by the westerly continuation of the "*Obolus*-beds"*

From this it would appear that conditions favourable to the pro-

* My Salt-Range Report, p. 207.

duction of such boulder-deposits recurred at intervals from the very close of the Salt-Marl period (1) through the whole time of the Purple Sandstone (2) and the succeeding Silurian *Obolus*-zone (3), where present, and that of the Speckled Sandstone (5) resting upon it, in the central and western parts of the Range; but in the eastern portion of this there was a more marked interval between the periods of the *Obolus*-beds (3) and the Speckled Sandstone (5), during which boulder-beds were not locally deposited at the stage occupied by the Magnesian Sandstone (4).

In detail, the western boulder-deposits are not suggestive of horizontal continuity, but rather of fugitive lenticular distribution, most strongly connected with the lower part of the series. In the central parts of the Range they are usually absent, or represented by a few dispersed conglomeratic layers at various levels; and in the east they are associated with the newer groups, while in their connexion and distribution in the "Olive Sandstones" (10) they recall the lenticular character of the western beds sufficiently to suggest a similar, later repetition of local conditions*.

The boulder-beds of the Eastern area, then, despite a certain amount of similarity, take their place upon a higher horizon than those to the west, the group in which they occur overlapping, with or without manifest unconformity, the Palæozoic groups, which themselves overlie, or are intercalated with, or represented by the western boulder-deposits.

In studying the relations of the Salt-Range Series on the ground, many of the natural groups, both in general aspect and in more detail, were found to present the arrangement called "dove-tailing;" notwithstanding this it was clear that the lower part of the whole series contained older Palæozoic fossils, and the upper part Mesozoic or newer remains. Thus far palæontological science has assisted in unravelling the physical problems of the geology of the Range, and has furnished recently some additional details as to certain of its most highly fossiliferous groups; but the full record, with its application, is as yet incomplete. If the dove-tailing arrangement obscures the succession in one place more than another it is in the region of the Kahún plateau, where the Magnesian Sandstone, the Speckled Sandstone, and salt pseudomorph groups all lose more or less of their distinctive characteristics between the horizons of the older Western and newer Eastern boulder-developments; and here the separation of elsewhere well-marked groups has been carried out upon the best general or special indications which each afforded. In this region, however, there was nothing found to unite the two boulder-groups upon one horizon; indeed, there was less difficulty in referring the "Olive group," of which the Eastern boulder-beds are members, to its place above, than in separating the

* Possibly combined with some amount of unconformity, if the appearances of a break exhibited on the road from Pind-Dadun Khan to Píd, which Mr. R. Oldham noticed (Rec. G. S. I. xix. pt. 2, p. 129), be accepted. The section here did not escape my observation; but the appearances of conformity elsewhere led me to regard it as probably an instance of local contemporaneous current-erosion.

lower groups from one another, where so many changes in the whole series take place.

Regarding the earlier portions of the general series, every thing connected with its oldest subdivision, the saline marl, salt, and gypsum-group, points to conditions of heat and evaporation; from these the change to a period of glacial severity, unaccompanied by a long interval marked by disturbance, would, according to the new theory, in some parts of the Salt-Range series, be remarkably abrupt; and it would seem more probable, from the so-called evidences of glaciation occurring only where there are records of rapid motion transporting coarse materials, that the glacial regions were removed vertically or horizontally, or both, by some considerable space from the present site of the boulder-accumulations.

Admitting that the *Conularia*-pebbles have been transported*, there is no great difficulty in supposing gradual alteration of conditions and alternation of events, as the natural causes operated, which could lead to the removal of glaciated boulders, and later could have transported fossiliferous pebbles or even nodules, each and both to be enclosed at different stages in the same deposits.

A prominent consideration regarding the layer with *Conularia* is—Whence came the pebbles enclosing the fossils? Their number and the extensive area occupied by the layer seem to indicate no very distant source, and the pale colour of the pebbles, of itself, seems to point towards the Magnesian Sandstone as the original site. The restricted character of the fossils as to their variety, and their attributed unity of age, may indicate that all came from a comparatively narrow zone or layer, the possibly local exposure of which to denudation might result from accident connected with the discordance noticed recently by Mr. Oldham (*l. c.*). The chief fact bearing against this supposition, so far as I am aware, is that many unavailing searches have been made for fossils in the Magnesian-Sandstone group; but this does not preclude the possibility of their occurrence.

Another consideration is that more than one previous observer has raised the question as to what became of the continuation of the Salt-Range series beyond its present southerly scarp. Fractures along a main line of fissure, coincident with this scarp, have been suggested; and dislocation of the kind, though impossible to trace, might have displaced beds from which the *Conularia* had been previously derived. At all events it is evident that there was formerly, in the vicinity of the Salt Range, a permanent source of foreign metamorphic materials, which became mingled with its ordinary deposits; and it does not seem to be a strained or very unlikely supposition, that the rocks of this old metamorphic region may have supported others, amongst which the original site of the *Conularia* and associated fossils was included—a region whence not alone the glaciated blocks, but all the rest of the Palæozoic, Mesozoic, and perhaps some of the earliest Kainozoic sediments of the Salt Range were derived.

* As Dr. Warth, Mr. R. Oldham, and myself maintain.

DISCUSSION.

Dr. DUNCAN said that the geology of the Salt Range was still subject to differences of opinion. The Range had been admirably surveyed by Mr. Wynne, but it did not appear that the succession of the strata and the conditions under which they had accumulated were consonant with the valuable results of the palæontology as described by Dr. Waagen. The Tertiaries, including the Nummulitic, overlay the Olive group, and this had been proved in Sind to be of Palæocene age and not Cretaceous. Was the Glacial bed at the base of this? or was it amongst the *Productus*-zone strata? or were there two glacial beds? These were questions which he did not consider could be satisfactorily answered by those who had paid attention to the late communications. The *Conulariæ* appeared to be the same as those of Australia; and Waagen's evidence as to the age of this as of the other stages of the Carboniferous, Permian, and Triassic groups was indisputable. He considered that the fracture proved that the *Conulariæ* were in concretions.

Mr. BLANFORD said he believed that Ammonites had been found in the Olive group, but the evidence was unpublished. He observed that one important distinction had been overlooked by Mr. Wynne. No one questioned that conglomerates containing pebbles of crystalline rocks occurred at different horizons in the Salt Range from Palæozoic to Tertiary. What was urged by Dr. Waagen was, that certain boulder-beds, occurring in three localities, very different in character from ordinary conglomerates, and containing large boulders, sometimes striated and imbedded in a fine matrix, were contemporaneous. The resemblance of these particular beds to each other had been pointed out by Mr. Wynne himself in his published papers.

The question as to whether the *Conulariæ* occurred in derived pebbles or not required further examination on the spot; but if they were derived from beds of the age of the Magnesian Sandstone, the boulder-bed containing them might be contemporaneous with the Speckled Sandstone, as Dr. Waagen contended.

The speaker took exception to some other points raised in the paper, such as the remarks upon the temperature of the Carboniferous seas and the correlation of the Cretaceous beds east and west of the Indus, but pointed out that one crucial test of Mr. Wynne's views was whether the boulder-bed of the Olive group in the eastern Salt Range could be traced to the westward, where that group rested on the *Productus*-limestone. That it could be so traced was indicated in Mr. Wynne's diagram; but no section was quoted in his paper, and the published section at p. 190 of the Salt-Range Report was opposed to that view.

Prof. SEELEY asked whether glaciated boulders were admitted by Mr. Wynne. The evidence of the explorer who surveyed the ground was always most important, and the physical questions ranked above the palæontological in value.

The PRESIDENT said that further evidence was required before the age of the band containing the *Conulariæ* could be considered definitely settled.

29. FURTHER PROOFS of the PRE-CAMBRIAN AGE of certain GRANITOID, FELSITIC, and OTHER ROCKS in N.W. PEMBROKESHIRE. By HENRY HICKS, M.D., F.R.S., F.G.S. (Read May 26, 1886.)

INTRODUCTION.

DURING a recent visit to Pembrokeshire I further examined some of the sections referred to in my paper communicated to the Geological Society in 1884* as well as others not there mentioned. The additional facts thus obtained are so important and so thoroughly confirm the views expressed in that paper, that I have felt it my duty to lay them before the Society. I referred so fully in my former paper to the rocks in the immediate neighbourhood of St. David's, and gave such ample evidence in support of my views, that it will be unnecessary to add much to it. Still as it is most important that some of the questions discussed in that paper should be settled beyond the possibility of doubt, I purpose giving such facts as are necessary to complete the evidence. Prof. Bonney has kindly undertaken to furnish notes on some of the rock specimens collected, and I am indebted to him for much valuable information concerning the conclusions at which he has arrived.

ST. DAVID'S.

Undoubtedly the point of greatest importance with which we have to deal, especially in its bearing on the controversy which has taken place in reference to the age of these rocks, is that relating to the Granitoid (Dimetian) rocks. The Director-General of the Geological Survey (Dr. Geikie) has definitely laid this down as the main question in the discussion. We maintain that the Granitoid rocks of this area, whatever their origin may have been, are of Pre-Cambrian age. Dr. Geikie, on the other hand, contends that they are intrusive in the Cambrian rocks. He says that after "the Harlech and succeeding groups of the Cambrian system were deposited . . . which had been laid down continuously without discordance . . . they were invaded by the rise of a mass of granite with the usual peripheral quartz-porphyrines"†, the mass of granite referred to being the Dimetian ridge of granitoid rocks extending from the city of St. David's to the coast near Nun's Chapel and to Porthelais and Porthlisky. I proved most conclusively, I think, in my former paper that the evidence relied upon by Dr. Geikie to show that the Granitoid rocks were intrusive in the Cambrian was based on erroneous observations. Not only is there no evidence of intrusion (and on this point, it must be remembered, my view is upheld most unhesitatingly by Professors Hughes, Bonney, and Blake, with several other observers), but I was even able to demonstrate that the Granitoid rocks occurred in that area before

* Quart. Journ. Geol. Soc. vol. xl. p. 507.

† Ibid. vol. xxxix. p. 324.

a grain of the Cambrian rocks had been deposited. In the specimens of the Cambrian conglomerate which were collected by me at different points on the former occasion and submitted to Mr. T. Davies for microscopical examination* abundant evidence was obtained to show that a very large amount of the material had been derived from Granitoid rocks. This was particularly the case with the specimens collected at and near Chanter's Seat, on the coast S.W. of Nun's chapel. During my late visit I again obtained specimens of the grits and conglomerates at Chanter's Seat, and I found them, in places, to be almost wholly made up of fragments of characteristic varieties of the Granitoid rocks found in the Dimetian ridge near by; therefore the facts prove most conclusively that the Granitoid rocks must have been present in the area in Pre-Cambrian times. Moreover certain peculiar structural appearances now observable in these rocks *in situ* are also equally evident in the fragments in the conglomerate (see notes on slides 1-5 by Prof. Bonney). The facts given with regard to the contents of the Cambrian conglomerates will, I think, be deemed an amply sufficient reply to some of the assertions made by Dr. Geikie in his paper, such as in the following passage, which occurs in his paper at p. 288.—“Dr. Hicks has stated more than once that the Cambrian conglomerates are largely made up of the underlying ‘Pre-Cambrian’ rocks. As the result of a most careful examination of the conglomerate belt along both sides of the fold, I feel myself warranted in stating confidently that it contains not a single pebble of the characteristic granite of the St. David's ridge.”

The distance between the point where the Dimetian fragments occur in greatest profusion in the Conglomerate, and the Dimetian *in situ*, is about 800 feet; but fragments are found also in the intervening series. When the Chanter's-Seat beds which belong to the Lower Cambrian series were deposited, it is clear that Granitoid rocks were being freely denuded; for on tracing the beds at this horizon for some miles to the east and also as far west as Ogof-llesugn, I found that they were very largely composed of the débris of such rocks. In the very lowest beds, however, there is a greater proportion of fragments from the Pebidians, and it seems tolerably clear that the Dimetian rocks were but little exposed when those beds were deposited, either from their being covered by Pebidian rocks or because of the presence of a great amount of loose material on the Pre-Cambrian land. The great thickness of Cambrian sediments found in almost all areas shows clearly that there must have been much loose material ready at hand to be washed away as each portion of the Pre-Cambrian land became submerged. This material must have accumulated during great and, possibly, peculiar atmospheric changes, as the rocks show clear indications of having been at the time subjected to powerful processes of disintegration. Almost all the rocks we claim to be of Pre-Cambrian age in the St. David's area are freely represented in the Cambrian conglomerates; and it is important to note that the fragments found of the Granitoid rocks, the felsitic rocks, the hälleflintas, the porcellanites, and the various

* See Notes 43-71. Quart. Journ. Geol. Soc. vol. xl. p. 553.

rocks of the Peibidian series show indisputably that these rocks must have assumed in all important respects their present peculiar conditions before the fragments were broken off (see notes on slides 6 and 7 by Prof. Bonney). Even the very newest of the Pre-Cambrian rocks, as is abundantly clear from an examination of the fragments in the Conglomerates, had been greatly crushed, cleaved, and porcellanized before any of the Cambrian sediments were deposited. The evidence to be obtained at St. David's therefore shows unmistakably that there is a great group of Archæan rocks now exposed in that area, and moreover that there is an undoubted unconformity, indicating an enormous lapse of time, between the lowest Cambrian Conglomerates and the underlying Archæan rocks.

BRAWDY, HAYSCASTLE, AND BRIMASTON.

The so-called granite indicated in the Survey maps as having been intruded into the Cambrian rocks in this area has been occasionally referred to in my papers. There are no coast-sections to show the nature of the contact between this so-called granite and the Cambrian; for the patch on the coast, also coloured as granite, as I shall explain further on, consists of a group of felsitic rocks. The area in which the so-called granite occurs is a cultivated district, and there are very few exposures to be found. I have at different times examined numerous points along the boundary shown on the map, in order to observe the contact between the Granitoid and the Cambrian rocks; but hitherto I have failed to meet with other than faulted junctions resembling the conditions found at St. David's. In no case could I find a particle of evidence to show contact-alteration, or any indication whatever that the so-called granite was intrusive in the surrounding rocks. During my recent visit I again traced some of the lines of junction, and with the same result. I could find no evidences of intrusion, but, on the contrary, the facts were such as to point almost unmistakably to the Granitoid rocks here being of Pre-Cambrian age, like those of St. David's. The Cambrian grit seemed, in places, made up largely of a granitoid débris, it being, indeed, in parts, little more than a re-arranged arkose. The Granitoid rocks here resemble in many respects some of those at St. David's, but on the whole contain more of the green micaceous mineral. The specimens described by Prof. Bonney from this area were obtained in a field near some cottages about a quarter of a mile east of Troed-y-rhiw. Large and fine-grained varieties are found here, as also some strongly brecciated bands, as in Porthelais valley, near St. David's; and an approximate junction between these and some of the Lower Cambrian beds is to be seen at Troed-y-rhiw and in the valley east of that point. A specimen from the Granitoid rock at Brimaston was described by Mr. T. Davies in his note 6 in my former paper (p. 548), and he there states that it "belongs to the Dimetian type." The facts obtained so far, therefore, tend strongly to confirm my view that this so-called granite, whether it is of igneous origin or not, is of Pre-Cambrian age and probably closely allied to the Dimetian of St. David's.

POINTZ CASTLE.

Extending along the coast south of Pointz Castle there is marked on the Survey map a mass of granite. This, as I have already stated, consists of a group of felsitic rocks, mainly rhyolites and breccias. Some of the rocks are spherulitic, others show flow-structure, and among them are some true breccias and beds of fine ash. There is no granite or any rock at all approaching in character to the neighbouring Granitoid rocks of Brawdy at present exposed there; hence the colour given in the map is highly misleading. The specimen described in the note on slide 10 by Prof. Bonney was obtained by me during my late visit at Cwm-bach, at the east end of the felsitic group, near the point of contact with the Lower Cambrian sediments. The contact here, as shown in a cliff face, is a well-marked line of fault. On the north side Menevian beds and *Lingula*-flags are faulted against the felsitic group, and there is not the slightest evidence of alteration to be seen in any of the sedimentary rocks at the junctions. The following are Dr. Geikie's remarks concerning this area, given in a footnote to his paper at p. 292.—“Mr. Peach and I had time to visit a few of the areas he [Dr. Hicks] has re-named, and always with the same result. Thus, on the coast near Newgale, about eight miles east of St. David's, he describes a mass of Pre-Cambrian beds, chiefly ‘felstones’ flanked by Cambrian conglomerates containing pebbles identical with the rocks below. All that we could find was an eruptive rock penetrating and altering black Cambrian shales.”

How Dr. Geikie could possibly have come to such a conclusion, I am at a loss to understand, even if he was unaware of the fact that the felsitic rocks were mainly flows and breccias; for the junctions are perfectly clear in good coast-sections. The Cambrian beds also along the north-east edge are sandstones, grits, and fairly rough conglomerates, and the latter contain fragments of felstones not to be differentiated from some of the rocks below.

ROCH, PLUMSTONE, AND TREGARN.

The rocks in these areas, which are coloured on the Geological Survey maps as intrusive felstones, and shown there and in the published section by the Survey to have produced much alteration in the various surrounding rocks belonging to the Lower Cambrian, *Lingula*-flag, and Llandeilo series, have been claimed by me on various occasions as being of Pre-Cambrian age, and I have contended that there is no evidence whatever to show that they have been intruded into the Palæozoic sediments, or that they have produced alteration in any of the surrounding sedimentary rocks. In my former papers I relied mainly on the facts obtained in examining the conditions at the junctions at different points where it was supposed alteration had taken place. I also found that the rocks indicated as altered Lower Cambrian in the Survey section were a series of volcanic rocks, ash, and breccias, greatly resembling those found in the other Pre-Cambrian areas and entirely unlike

any of the undoubted Cambrian rocks of the district. I further noticed, in following the boundaries of these so-called intrusive rocks, that the junctions were mainly faulted ones. Dr. Geikie, however, in his papers and elsewhere, still maintains that the views indicated in the Survey maps and sections are perfectly correct. Fortunately, since my last paper was read, Mr. Marr and Mr. T. Roberts have published in the Quart. Journ. Geol. Soc. vol. xli. p. 476, a paper on the Lower Palæozoic rocks of this neighbourhood, which contains facts of the utmost importance in regard to the questions in dispute. During their researches they noticed, in a quarry near Trefgarn Bridge, an exposure of rocks of a similar character to those found in the Pre-Cambrian volcanic series about half a mile further north. Resting on these, quite unconformably, they also found a conglomerate containing large pebbles which appeared to have been derived from the underlying rocks. Upon the conglomerate and grit were some black shales, and in these they found *Olenus spinulosus* and other fossils, proving them to be of the age of the Lingula-flags. They also state that the shales are considerably disturbed, that there are signs of faulting in the quarry, and that the conglomerate adheres to the underlying "ashy-looking rock." During my late visit I examined this quarry with some care, and I fully concur in the interpretation given by Messrs. Marr and Roberts. I was also fortunate enough to see an exposure, in the quarry, of the rock we have hitherto designated hälleflinta, which is so characteristic of the Roch and Trefgarn mountain-series. I was particularly pleased at finding this, as it proved conclusively that the rocks underlying the conglomerate could in every important particular be correlated with the Trefgarn and Roch series. This proof that they extend to a distance of half a mile further south than I had previously indicated them is also of importance. The so-called hälleflinta is now exposed on the right-hand side after entering the quarry from the road; but a heap of débris covers the face of the quarry between the hälleflinta and the ash-bands, so that the actual contact between them is not seen. The ash is, in some places, fine and compact, but at other points it is a distinct breccia. The beds lie at a high angle, therefore the unconformity between them and the conglomerate is most marked. The latter lie evidently on an irregularly eroded surface. Specimens taken from the so-called hälleflintas and the ash-bands are described by Prof. Bonney in his Notes on slides 11-13. In the conglomerate very large pebbles of the hälleflinta and of the ash are abundant. The slide No. 14 was cut from a pebble over 5 inches across in one direction and $3\frac{1}{2}$ in the other, and Nos. 15 and 16 from pebbles measuring 2 and $3\frac{1}{2}$ inches across. The latter are much flattened and crushed. The similarity between the hälleflinta pebble and the rock *in situ* in the quarry as well as to the rocks at Trefgarn Mountain and Roch Castle is most remarkable, and proves indisputably that the curious changes which these rocks have undergone must have taken place in Pre-Cambrian times.

This conglomerate, as shown by the fossils in the overlying shales,

cannot be newer than the Lingula-flags; and, indeed, it seems almost certain that it must be of Lower Cambrian age, and that it happened to be left here lying on the Pre-Cambrian eroded surface when the beds between it and the Lingula-flags were cut out by the fault. That the volcanic series at Trefgarn and Plumstone mountains are older than the Lowest Cambrian rocks in those areas, there cannot be the shadow of a doubt; therefore there is every reason to believe that the rocks of the same nature in this quarry are also of that age. In any case the evidence here is perfectly conclusive as to their being older than the Lingula-flags (Upper Cambrian). Therefore the Survey maps and sections are misleading in indicating any of these as intrusive masses in Cambrian and Silurian sediments.

CONCLUSIONS.

The new facts now laid before the Society, combined with those given on previous occasions, show that there is exposed in N.W. Pembrokeshire a great group of Pre-Cambrian rocks. There are also material differences to be made out in these Pre-Cambrian rocks at various points, and there are indications pointing to their being of different ages; the Dimetian rocks are evidently the oldest, and some of the indurated argillites and the more basic portions of the Pebidian series the newest. The position of the great felsitic series (Arvonian) is certainly between the Dimetian and Pebidian, but it is difficult to state decidedly whether it should be classed as of Pre-Pebidian age. From the facts to be obtained at Ramsey Island, also to the north of St. David's, and elsewhere, I am still inclined to look upon that series as marking a definite period. Still it must be admitted that at present the evidence for this is not conclusive. That the newest of the Pebidian rocks must have been folded, cleaved, and have undergone great structural changes before the Lower Cambrian Conglomerate was deposited is absolutely certain, as the conglomerate rests quite unconformably on the Pebidians, and the rolled fragments of the latter found so abundantly in it show clearly that the Pebidians had undergone all their important changes before the fragments were broken off. That the underlying felsitic and Dimetian rocks had also assumed their peculiar characters in Pre-Cambrian times, is equally certain, as may be seen by examining the rolled fragments so plentiful in some of the Cambrian grits and conglomerates.

The presence of these fragments in the Conglomerate is also conclusive proof that the Dimetian and the felsitic rocks are not intrusive in the Cambrian and Silurian sediments, but are, as previously claimed by me, undoubtedly of Pre-Cambrian age.

I therefore maintain that there is the most ample evidence to show that there is a great group of Pre-Cambrian rocks exposed in N.W. Pembrokeshire, and hence that I have proved conclusively that Dr. Geikie's views in regard to these rocks, as given in his paper and more recently in his text-book, are entirely erroneous.

(For the DISCUSSION on this paper, see p. 363.)

30. *On some ROCK-SPECIMENS collected by Dr. HICKS in N.W. PEMBROKESHIRE.* By T. G. BONNEY, D.Sc., LL.D., F.R.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read May 26, 1886.)

THE specimens collected by Dr. Hicks during his late visit to Pembrokeshire have a most important bearing on the question of the existence or non-existence in that region of a considerable group of Pre-Cambrian rocks. In addition to these, the slides described by Mr. T. Davies in the 'Quarterly Journal' for 1884 were placed in my hands for purposes of comparison. I also possess a small series cut from specimens either collected by myself on occasion of a short visit in 1882 or given to me by Dr. Hicks.

The main points at issue in regard to the geology of the district are these: Do we find here an important group of rocks anterior to a well-defined base of the Cambrian series? or are certain granitoid and felsitic rocks (the so-called Dimetian and Arvonian) only intrusive masses of later date than the lower Cambrian? and is the so-called Pebidian merely a record of volcanic eruptions which occurred in the earliest days of the Cambrian period, no more deserving of separation from it than are the volcanic rocks of the Arenig or Bala from the other members of those formations? Subordinate and highly interesting questions are: What is the true nature of the granitoid (Dimetian) and of the felsitic (Arvonian) rocks? Are they metamorphic rocks in the ordinary sense, or are they igneous? If the former view can be established, the controversy is practically at an end; but if the matter must remain in uncertainty, or even if the rocks be proved in both cases to be igneous, they may yet be Pre-Cambrian, and the question must be settled by stratigraphical evidence.

CAMBRIAN CONGLOMERATE OF CHANTER'S SEAT.

The first group of specimens which I have to describe is from the Cambrian conglomerate near Chanter's Seat. The matrix of this conglomerate is greenish grey in colour, a little brown on slightly weathered surfaces. The appearance of the rock suggests that it is a kind of arkose. A portion of it bears considerable resemblance to parts of the Dimetian of St. David's and of the granitoid rocks from Brawdy when locally crushed. It is crowded with specks of light-coloured felspar, grains of quartz, and rather well-rounded little pebbles, usually not exceeding $\frac{1}{4}$ inch in diameter (about 0.2 inch is a common size); many of these are quartz, others evidently a granitoid rock. After Mr. T. Davies's excellent description of specimens from this locality and elsewhere (Quart. Journ. Geol. Soc. vol. xl. p. 548), I need not enter into minute details.

The slides all abound in quartz-grains, sometimes well rounded, many of which, in the nature and arrangement of the inclusions,

exactly resemble the quartz in the Dimetian. In each there is the same "dirty" look, produced by numerous inclusions, many of which are irregular in form, more like mineral films, some fluid-cavities with bubbles. The sections contain numerous fragments of felspar, very similar to that in the Dimetian; in short, they present every appearance of an "arkose" to which granitoid rocks have largely contributed. Six out of the seven slides include well-marked fragments of granitoid rock. A description of the largest in the slide numbered (1) will suffice for most of the others. It is about .2" in diameter, containing some eight crystals or parts of crystals of felspar (rather decomposed) and nearly as many grains of quartz, besides a couple of spots of a yellowish-green mineral, probably replacing a magnesia-mica. The felspar crystals, which vary much in size, are very like those in the Dimetian; so is the quartz, and the method of association of the two minerals is the same. In all respects the section of this fragment curiously resembles the slides of "Dimetian" rock.

There are two other fragments in this slide, the smaller exhibiting a micrographic arrangement of the quartz and felspar (*quartz de corrosion*?) which is common in the Dimetian. Slide (2) has three fragments; (3) has one; (4) has two; (5) has three. I have enumerated only those which are indubitable. Besides this, 2, 3, 4, 5, 6, 7, exhibit rolled fragments of a volcanic rock. Some are a brown-stained, rather opaque lava, probably a not very siliceous trachyte or andesite; others, less common, are varieties of a trachytic rock showing innumerable microliths of felspar (probably plagioclase), with granules of iron oxide, in a base perhaps still glassy; in one or two occur patches of a green mineral, probably replacing a mica; one fragment is a devitrified rhyolite in which the quartz is partially aggregated in nests. One slide (3) has a fragment of a rather banded rock, exhibiting the cherty structure characteristic of a "hällefinta." Two or three have quartzite, in two cases schistose; and one (7) contains a fine-grained quartz-schist, with a structure which reminds me of some of the compressed quartzose schists of the Highlands. One or two also contain bits of an argillite.

I perfectly agree with Mr. T. Davies in his identification of the contents of these conglomeratic rocks, and can only say that if a considerable number of the fragments have not been derived from the so-called Dimetian, they have come from a rock which bears the most extraordinary resemblance to it. The latter hypothesis is so improbable that I cannot hesitate to adopt the former.

SPECIMENS OF ROCKS AND OF PEBBLES FROM THE OVERLYING CONGLOMERATE AT TREFGARN.

The peculiar rocks from Trefgarn and Roch Castle have already been noticed, as regards their microscopic structure, by Mr. T. Davies and Prof. Blake. Certainly they are not normal felstones. In the field, to the eye, to the touch, under the hammer, they have

a sort of cherty character, which at once attracts the notice of an experienced observer. They differ in these respects from all the old rhyolites of North Wales, the Wrekin, Charnwood, &c., which I have seen. They have no resemblance to the ordinary intrusive felstones of similar chemical composition. There is also something distinctly exceptional about their microscopic structure. I have repeatedly examined during the last few years the slides in my own collection and in that of Dr. Hicks, and for a long time I felt the greatest perplexity as to their nature. In some respects they recalled the structure of devitrified rhyolites of a very glassy type (obsidian); in others they seemed more like a chert or a much-altered rock of sedimentary origin (hälléfint); but after seeing Prof. Blake's specimens I felt more satisfied as to their nature, and my view has been borne out by these new examples.

I proceed to describe the specimens (three in number) obtained from rock *in situ* beneath the conglomerate:—

(11) A greenish-grey rock of fragmental aspect, perhaps slightly cleaved, apparently an altered ash. Microscopic examination shows that it is made up wholly of fragments, which are clearly of volcanic origin,—bits of an acid microporphyrific lava full of small felspar crystals, orthoclase and plagioclase (oligoclase?),—in a base which is now probably wholly devitrified, but was once a glass more or less crowded with opacite and felspar microliths. To enter into minute details would be only to travel over old ground; the rock may, without hesitation, be named a volcanic ash, which might be either a member of the earlier Palæozoic series or somewhat older than that.

(12) A similar rock, but a little more compact and uniform in appearance. The microscopic structure indicates a like origin. One or two fragments are quite opaque from the quantity of opacite, as is often seen in the scoria even of trachytes. Here and there are little nests of an aggregated serpentinous mineral, no doubt secondary replacements of some pyroxenic mineral. This is also an altered volcanic ash.

I am indebted to Mr. J. J. H. Teall for the use of a third specimen, a very similar indurated ash. The fragments in all three appear to me rather intermediate in character between an andesite and a sanidine-trachyte, but to be more nearly related to the former.

(13) A purplish rock with the peculiar flinty aspect of the most typical "hälléfintas" of Trefgarn and Roch Castle. Under the microscope it exhibits the characteristic structure of these rocks. With ordinary light the ground-mass is partly clear, partly tinted by extremely minute granules of ferrite, so arranged as to suggest a fluidal structure, though irregular and indistinct. Here and there are either cracks, or small elongated cavities occupied by crystalline quartz and opacite. With crossed nicols the ground-mass exhibits the peculiar speckled aspect which, while bearing some resemblance to a very minute devitrification-structure, also reminds one of that usual in a chert, and in some hälléfintas of sedimentary origin. A specimen from this quarry given to me some years since

by Dr. Hicks, of a buff colour, resembles the above in most respects, but there are no cavities, and there is more opacite, which is arranged in cloudy streaks and patches, suggesting a fluidal structure.

The slides from Roch Castle, described by Mr. Davies, exhibit fluidal structure, felspar crystals replaced by chalcedonic quartz, and cavities of various forms, from well-rounded to elongated and irregular in outline, filled by secondary deposits of this mineral.

Three specimens of the pebbles in the conglomerate at Trefgarn have been examined.

(15) A pebble of grey ashy-looking rock very like (11). Under the microscope it presents varietal differences, the structure not being quite so certainly that of an ash. The felspar-crystals are less numerous, larger in size, and a greater proportion are plagioclase. There is also rather more iron oxide than in the rocks numbered 11 and 12. I think, however, the rock is probably an ash, though it is just possible that flow-brecciation, followed by some crushing, might explain this structure. There is no more difference between this and the last-named rocks than might easily be found in the ejecta of any volcano.

(16) A rather similar rock, probably an ash; felspar crystals more numerous and ground-mass more completely devitrified than in the last case.

These rocks are not so well preserved as are those *in situ*; they appear also to be a little crushed. Hence it is difficult to be quite certain as to their origin, but I think it is far more probable that they are a somewhat altered volcanic ash. In any case I have no doubt they have been derived from members of the Trefgarn series*.

(14) A buff-coloured rock, part of a large pebble, which macroscopically exactly resembles the typical hällfintna of Trefgarn, having the same flinty aspect, &c. The microscopic structure is in all respects identical, except that there are hardly any cavities; the ground-mass is very slightly coarser and more like that of an ordinary devitrified obsidian. Still it has been to some extent subsequently silicified. When we examine the structure of the matrix with high powers the identity is still more strongly maintained. For instance, this specimen contains a great number of belonites, commonly varying in length from .0005 to .001 inch; their extinction appears to be at a small angle with the longer edge, and I think it probable that they are hornblende. There are a few specks of ferrite and granules of iron oxide (?); these are often grouped irregularly in cloudy patches. The same belonites occur in the two slides from rocks *in situ*, though in these there are fewer belonites, and there is rather more ferrite. The devitrified structure is singularly alike in both cases.

I cannot doubt that these pebbles have been derived from the

* All who have worked much at volcanic ashes which have undergone considerable micromineralogical change, such as those of the Lake District, North Wales, and Charnwood, know that occasionally specimens occur of which it is most difficult to say whether they have been originally glassy lavas or homogeneous ashes.

underlying series. I may mention that, in the case of (14), the hand-specimen presents no marked indication that it is from a pebble, and I examined it for some time under the impression that it was from the subjacent rock, and did not find out my mistake until I noticed the label*.

ORIGIN OF THE "HÄLLEFLINTAS" OF TREFGARN AND ROCH.

I have compared these slides from the rocks of Trefgarn and Roch with specimens in my own collection of obsidians and pitchstones from various localities, and with slides of devitrified rhyolitic rocks from below the Cambrian conglomerate near Llanberis, from the Wrekin, and from large fragments in the volcanic ashes of Charnwood. To many of these they present close resemblances; the belonites and the arrangement of the ferrite and opacite can be paralleled by the former (glassy) rocks †; the devitrification-structure by that in the latter group, though sometimes there are differences due to silicification. But while this structure is more normal in these rocks than in those from Trefgarn and Roch, the microporphyratic and amygdaloidal characters are more conspicuous in the latter, and the fragments in the ash-beds of Trefgarn are of a perfectly normal character. Hence I regard the series, on the whole, as indubitably a volcanic one, consisting of acid lavas and their associated ashes, some, especially of the former, having been, as suggested by Prof. Blake, subsequently permeated by hot water containing silica in solution, which has silicified the rock, replacing the feldspars and, in part, even the feldspathic constituent, by chalcedonic quartz and filling up the cavities with the same. This process need not have occurred long after the emission of the lava, though I believe it was subsequent to the devitrification of the rock; but, in any case, the ash-beds of Trefgarn (which are not silicified) must have become very hard, by means of ordinary micromineralogical change, before the pebbles were made from them, and so must be much older than the overlying conglomerate.

The general similarity of the unsilicified rocks of Trefgarn—and to some extent even of the silicified—to the rhyolitic, trachytic, or andesitic rocks which abound in the Cambrian conglomerate and the underlying breccia, is an argument for the fragments in these being derived from lavas of about the same age as those at Trefgarn. Moreover the Roch and Trefgarn rocks are practically identical; the latter cannot be intrusive, the former (even if there be no ash-beds there) has all the structure of a flow as opposed to an intrusive mass; hence we may safely say that the series, as a whole, cannot be intrusive in beds of "Harlech" or later date.

ROCKS FROM BRAWDY AND CWMBACH.

Granitoid rock from Brawdy (2 slides).—This rock is holocrystalline, consisting of quartz, decomposed feldspar (among which plagioclase, probably oligoclase, and orthoclase may be occasionally

* To avoid any prejudice I usually, in the first stage of my examination of specimens collected by others, abstain from looking at labels or notes.

† *E.g.* by specimens from Mexico, Arran, Meissen.

recognized), and a fair proportion of a greenish micaceous mineral (altered biotite). One slide shows much crushing, the rock being in places brecciated *in situ*. It may be a granite, but the structure is a little abnormal. We have in it the same difficulty as is presented by the Dimetian of St. David's, and by the granitoidites of Twt Hill, Ty Croes, and Ercal (Wrekin). Under these circumstances, though we cannot prove the Brawdy rock to be of Archæan age, this identification is the more probable.

Owm Bach, near Newgale.—A pale greenish-grey, flinty-looking rock, with lighter specks, resembling an altered ash, such, for example, as some of that near Clegyr Bridge. There are crystals of felspar (some oligoclase) which are evidently broken and corroded by the ground-mass, which exhibits a minute devitrified structure, with a few grains of iron oxide and one or two of a green serpentinous mineral. The microscopic examination does not give a result which is absolutely beyond dispute. There is just a possibility that the rock may be a rhyolite with flow-brecciation; but I have little doubt that it is a true indurated ash.

CONCLUSIONS.

The following conclusions, then, appear to me to follow from the above investigations:—

A. When the Chanter's Seat conglomerate was formed the following rocks were undergoing denudation:—

- (1) Granitoid rocks, identical with the existing Dimetian.
- (2) Trachytic rocks, among which were probably true lava-flows*.
- (3) Quartzites and schists, the latter resembling those which in many districts occur rather high in the Archæan series.
- (4) Ordinary sedimentary rocks.

Hence there was in this district a series of rocks, some much older than others, which contributed to the formation of the Cambrian conglomerate.

- B. The conglomerate above the Trefgarn series is formed from rocks which occur in the latter.
- C. The peculiar characteristics distinctive of certain members of the Trefgarn series had been assumed by them when the conglomerate was formed.
- D. Either the Dimetian is a member of an old gneissoid series or, if it is the core of a volcanic group from which the trachytic lavas had been ejected, this had been laid bare by denudation before the Cambrian conglomerate was formed. Hence in either case both the Dimetian and the felstones are Pre-Cambrian.

* It is quite true that we cannot, in our present stage of knowledge, fix upon any structure as distinctive of a lava-flow, but there are many which only occur in rocks cooled under conditions very similar to those of flows; and when we find fragments exhibiting these occurring in great variety and abundance, the probability is very strong that they are derived from subaerially consolidated masses. Indeed, as similar structures could only occur elsewhere in dykes and small intrusions, it is not likely that in this case they could furnish many fragments.

We have, then, in Pembrokeshire exactly the alternative presented in Caernarvonshire and Anglesey * ; and in either case it results that the granitoid rocks, whether igneous or not, are much older than the conglomerate, so that the latter forms a good base to the Cambrian-series. From these conclusions I see no way of escape, except by denying the facts on which they are founded.

DISCUSSION.

The PRESIDENT said that these papers dealt with one important branch of the discussion concerning the age of the rocks of St. David's. It is a crucial point to ascertain whether detritus derived from the rocks called Dimetian occurs in the Cambrian ; and that this is the case the Authors consider that they have succeeded in proving.

Prof. BLAKE thought the question had been fairly threshed out before ; he only regretted that the examination had not been transferred to a locality where the evidence is clearer than at St. David's. He suggested that the Harlech area would afford important results.

Mr. MARR said that Mr. Roberts and himself, in their paper on the neighbourhood of Haverfordwest, had spoken with caution about the age of the volcanic ashes they had observed, and the subsequent discovery of ashes in the Lingula-flags justified their caution ; but the evidence now brought forward by Dr. Hicks confirmed their suggestion. He called attention to the resemblance of the hälleflintas to siliceous sinters.

Mr. TRALL said that the specimens of rock from Trefgarn which he had partially analyzed for Mr. Marr yielded SiO_2 97.5 %, Al_2O_3 , Fe_2O_3 , 1.1 %, loss on ignition 1.8 %.

Dr. SELWYN said it was so long since he had examined the Welsh rocks that he had almost forgotten them, but he had seen rocks of similar aspects in Canada, and was now convinced that the metamorphic rocks of Anglesey and Caernarvonshire were not altered Cambrians. So far as North Wales was concerned, he was inclined to agree with Dr. Hicks. At the same time it was extremely difficult to classify these ancient formations, and generally it was impossible to determine which was the top and which the bottom of the sequence. In Cape Breton, Nova Scotia, however, unaltered Lower Cambrian rocks were found resting unconformably on highly altered rocks, gneiss, &c., presumably of Laurentian or Huronian age.

Dr. HICKS, in reply, thanked the Fellows, and especially Dr. Selwyn, for their remarks, and said he had more evidence to bring forward, if necessary. He considered Dr. Selwyn's original descriptions of the North-Wales rocks most valuable.

Prof. BONNEY thought it doubtful whether any of the rocks at Roch Castle were originally sinter. The hollow structure is probably vesicular. At the same time he was not surprised to find that the rock consisted almost entirely of silica, for the microscope showed that the felspathic constituent in the rock had been almost wholly replaced by silica.

* Quart. Journ. Geol. Soc. vol. xl. p. 200.

31. *Note on some VERTEBRATA from the RED CRAG.*

By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read May 12, 1886.)

THE examination of certain specimens from the Red Crag in the collection of the British Museum, which have been already described by other writers, and the recent acquisition by the same collection of casts of a small series of remains from these deposits, which were collected by the Rev. Mr. Canham and are now in the Ipswich Museum*, have enabled me to make some additions and emendations to our knowledge of the vertebrate fauna of the Red Crag which it appears desirable to notice collectively.

Hyæna.—The remains of *Hyæna* from the Red Crag hitherto described comprise two upper and one lower third premolars, all of which are referred by Lankester† to his *H. antiqua*, which was founded on the specimen first obtained. This so-called species was regarded as closely allied to the existing *H. striata*, but the specimens are really insufficient for specific diagnosis; and it may be remarked that it is, *primâ facie*, exceedingly improbable that the Crag *Hyæna* should be distinct from all continental forms. The occurrence of *H. striata* in the caverns of France has been determined by Gervais‡, while Gaudry§ remarks that the so-called *H. arvernensis*, Cr. & Job., from the Upper Pliocene of the Auvergne and the Val d'Arno appears undistinguishable from the existing species, although the name is still retained by Forsyth-Major||. In recording a specimen of the maxilla of a *Hyæna* from the Val d'Arno in the 'British Museum Catalogue of Fossil Mammalia'¶, I referred it unhesitatingly to *H. striata*; but being uncertain as to its exact age, I did not identify it with *H. arvernensis*, and suggested that it might be from the Pleistocene.

The Ipswich Collection contains the right upper carnassial of a *Hyæna* (fig. 1), which is quite undistinguishable from the corresponding tooth of *H. striata*, and, from its age, may be safely referred to *H. arvernensis*. That this tooth is specifically the same as *H. antiqua* there is also no reasonable doubt; and from the impossibility of distinguishing it from pm. 4 of *H. striata*, I conclude, with Gaudry, that *H. arvernensis* is probably identical with that species, since I cannot find any point described which can be regarded as a specific difference**. The slight differences noted by Lankester in comparing

* I have to express my thanks to Dr. J. E. Taylor, F.G.S., the Conservator of the Ipswich Museum, for permission to bring these specimens to the Society's notice. I am also indebted to Mr. Alfred Bell for some information as to the locality and horizon of two of the specimens.

† Quart. Journ. Geol. Soc. vol. xxvi. pp. 511, 512 (1870).

‡ Zool. et Pal. Franç. 2nd ed. p. 241 = *H. prisca*.

§ Anim. Foss. et Géol. de l'Attique, p. 103.

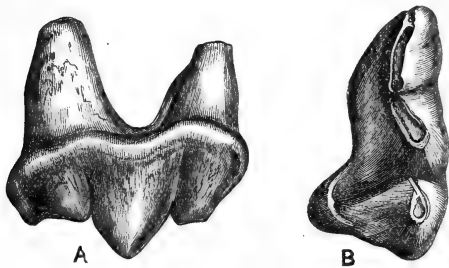
|| Quart. Journ. Geol. Soc. vol. xli. p. 4 (1885).

¶ Part i. p. 88, no. M. 469 (1885).

** This would lead to the inference that the British Museum Val d'Arno specimen was probably obtained from the typical Upper Pliocene of that region.

the type pm. 3 of *H. antiqua* with that of *H. striata* are not greater than the differences occurring in the corresponding teeth of different individuals of *H. crocuta*; and it may be observed that since *Hippopotamus amphibius* occurs in the Upper Pliocene of the Val d'Arno, there is no inherent improbability in the *Hyæna* of the same beds being likewise identical with an existing species.

Fig. 1.

*Hyæna striata (arvernensis).*

The right upper carnassial, from the outer (A) and oral (B) aspects; from the Red Crag at Trimley St. Mary. Natural size.

Mastodon.—With the exception of those of *M. arvernensis*, most of the molars of *Mastodon* from the Red Crag are so imperfect and so much rolled that their specific determination is frequently a matter of much difficulty; and when to this is added the confusion that formerly existed between the teeth of *M. Borsoni* and *M. turicensis*, it is not to be wondered at that some doubt has existed in regard to the species occurring in the Crag. The specimens I have had the opportunity of seeing indicate that in addition to *M. arvernensis*, both *M. longirostris* and *M. Borsoni* are represented in the Crag fauna. I may first call attention to two very beautiful examples of the penultimate upper milk-molars of *M. arvernensis* in the Ipswich Collection, which have not been rolled, and therefore exhibit very clearly all the characteristic features of the teeth of that species. The evidence for the presence of *M. longirostris*, Kaup, is afforded by several fragments of molars in the British Museum*, and by the greater part of a second or third upper true molar † figured by Lankester in vol. xxvi. pl. xxxiv. figs. 1, 2, of the Society's 'Journal,' and regarded by him as the complete tooth of a trilophodont species. The examination of the cast of the latter shows, however, without doubt, that it has lost one or more posterior ridges, and that, as suggested by Lartet ‡, it really belongs to *M. longirostris*, the form of the anterior talon and the separation of the inner and outer

* These and the preceding specimens will be noticed in part iv. of the 'British Museum Catalogue of Fossil Mammalia.'

† Cast in Brit. Mus.

‡ See Lankester, *op. cit.* p. 508.

columns being decisive. A small tooth in the Ipswich Museum Collection is evidently a lower premolar, and I am inclined to regard it as the penultimate one of the present species. With regard to *M. Borsoni*, I think that the specimens figured by Lankester, *op. cit.* figs. 3, 4, and provisionally referred to *M. turicensis (tapiroides)**, really belong to this species. There is a trilophodont ultimate upper milk-molar in the British Museum (No. 46690) which I also provisionally refer to *M. Borsoni*, while the Museum of Practical Geology in Jermyn Street possesses the last two ridges of a second right upper true molar presenting all the characters of the teeth of this species.

Sus.—In the Cat. Foss. Mamm. Brit. Mus. pt. ii. p. 268, I have noticed two third lower true molars of a large *Sus* from the Red Crag which closely resemble the corresponding teeth of the Pikermi *S. erymanthius* †, but are of rather smaller size. A third left upper true molar in the Ipswich Collection agrees exactly in size with the corresponding tooth of some specimens of that species, and therefore probably indicates the occurrence either of that species or of the closely allied *S. antiquus*, Kaup, in the Crag. The smaller Crag species has been provisionally referred to *S. palæochoærus* ‡.

Tapirus.—The Red-Crag Tapir has been identified with the Eppelsheim *T. prisus*, Kaup §, but its teeth agree more nearly in size with those of *T. arvernensis* and the closely allied *T. elegans* of the Upper Pliocene of the south of France ||.

Hipparion.—The remains of *Hipparion* from the Crag have been referred to *H. gracile* ¶, although it has been suggested by Depéret** that they may belong to the Pliocene *H. crassum*, Gervais, which the former writer regards as distinct, although it appears very difficult to distinguish the teeth.

Rhinoceros.—Most of the molars of *Rhinoceros* from the Red Crag in the British Museum which have been referred to *R. Schleiermachi* †† present the characters of those of the hornless *R. incisivus*, and I am therefore disposed to refer them to the latter species ‡‡, although it is highly probable that *R. Schleiermachi*, and perhaps *R. etruscus*, may also occur in the Crag.

Diomedea.—By far the most interesting of the specimens to which I have to call attention are the associated right tarso-metatarsus and proximal phalangeal of the outer (4th) digit of a large bird in the Ipswich collection. I have compared these specimens (fig. 2) with the corresponding bones of *Diomedea* in the Museum

* In his description of the Crag specimens, Lankester (pp. 508, 509) has unfortunately transposed the characteristics of *M. Borsoni* and *M. turicensis*.

† Probably identical with *S. major* of the south of France (Lower Pliocene). This name has the priority, but it appears advisable to adopt *S. erymanthius*.

‡ See Cat. Foss. Mamm. Brit. Mus. pt. ii. p. 273.

§ Owen, Quart. Journ. Geol. Soc. vol. xii. p. 233 (1856).

|| Lydekker, Cat. Foss. Mamm. Brit. Mus. pt. iii. p. 3 (1886).

¶ *Ibid.* p. 54.

** Thèses, Faculté d. Sciences d. Paris, sér. A, no. 67, pp. 195, 196 (1885).

†† Owen, *op. cit.* p. 231.

‡‡ Lydekker, *op. cit.* p. 149.

of the Royal College of Surgeons, and find the resemblance so exact, even down to the most minute ridges and grooves, that there can be no reasonable doubt as to their belonging to the same genus. They indicate a species intermediate in size between the largest examples of *D. exulans* and the smaller *D. melanophrys* and *D. chlororhyncha*; but it would be unsafe to make any attempt at specific determination. It may be added that an imperfect wing-bone of a large bird from the Coral-line Crag in the Museum of Practical Geology may perhaps belong to the form under consideration. The unrolled condition of the specimens indicates that they are not "derived" fossils; and Mr. Alfred Bell informs me that they were obtained in company with a very fine *Rhinoceros*-tooth (which, he thinks, may be *R. etruscus*) from a sandy bed immediately overlying the shelly Red Crag at Foxhall, which, I am informed, is regarded by some geologists as part of the Red Crag, but by others as somewhat newer. Mr. Bell also informs me that the genus of these bones was determined many years ago by Mr. Gerrard, of the British Museum, although no record of the determination was published.

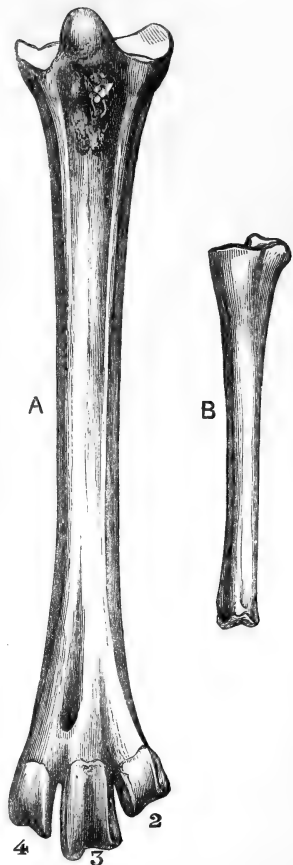
The genus *Diomedea* is represented at the present day by several species; but I am unacquainted with any previously described fossil form*. As *D. exulans* is found throughout the Southern Ocean and the sea washing the coasts of Asia to the south of Behring's Straits, there is no reason why the range of the genus should not formerly have embraced the North Sea.

DISCUSSION.

The PRESIDENT remarked on the fragmentary character of the Red-Crag Vertebrata and their frequently rolled condition, and expressed

* *Pelagornis* from the Miocene of Armagnac (Gers) has been thought to be allied to *Diomedea*, but it is regarded by Milne-Edwards ('Oiseaux Fossiles de la France,' vol. i. p. 272) as more nearly related to *Sula*. The tarso-metatarsus appears to be unknown.

Fig. 2.



Diomedea, sp.

The right tarso-metatarsus (A) and first phalangeal of the fourth digit (B), from a sandy bed at the top of the Red Crag at Foxhall. Natural size.

his satisfaction at the interesting additions made by Mr. Lydekker to our knowledge.

Prof. FLOWER entirely confirmed the President's views. He hoped the nomenclature in the British Museum would be much more correct since Mr. Lydekker had undertaken the cataloguing of the Mammalian fossils. The speaker was well acquainted with the Canham collection in the Ipswich Museum, and made some observations on the interesting specimens contained in it. The bones of Albatross furnished an especially valuable addition to the British extinct fauna.

Mr. E. T. NEWTON was disposed to agree with Mr. Lydekker's conclusions. The discovery of the Albatross was most interesting; he had himself seen some additional Pliocene birds' bones lately, one of which belonged to a bird of prey. The bird-bone in the Jermyn Street Museum noticed by Mr. Lydekker was from the "Coralline Crag" and had been presented many years ago by Col. Alexander.

Dr. WOODWARD said that Col. Alexander had formerly a house at Bramerton near an outcrop of Norwich Crag, so that it was possible that the bones mentioned by Mr. Newton were derived from that deposit. Mr. Lydekker had had the advantage of studying the original specimen from the Ipswich Museum as well as the beautiful casts on the table.

The AUTHOR in reply gave some details as to the distribution of Pliocene and Pleistocene Mastodons.

32. *On the GLACIATION of SOUTH LANCASHIRE, CHESHIRE, and the WELSH BORDER.* By AUBREY STRAHAN, Esq., M.A., F.G.S., H.M. Geological Survey. (Read May 26, 1886.)

(By permission of the Director General.)

PART I.

South Lancashire and Cheshire.

THE occurrence of glacial striæ in the neighbourhood of Liverpool was first recorded by Mr. G. H. Morton, F.G.S., in 1859*, though they had been previously noticed by Mr. J. Cunningham, F.G.S. † In 1862‡ Mr. Morton described before this Society and the Liverpool Geological Society striæ on both sides of the river Mersey. Prof. Hull in 1864§ recorded the striæ of Bidston Hill, pointed out to him by Mr. Cunningham, remarking that they point in the same direction as those of Liverpool. These had been previously noticed by Mr. Morton as having the precise direction N. 30° W.

In consequence of his discovery of striæ on both sides of, but at no great distance from, the Mersey, Mr. Morton in 1866|| advocated the hypothesis of a glacier having descended the valley of the river; but in 1870¶, having discovered similar markings away from the river, adopted the theory of an ice-sheet having passed over this part of the country from S.E. to N.W.

In the same year Dr. Ricketts, F.G.S., recorded striæ at Thatto Heath**, and stated that the moving power which produced them had taken a course from south-east to north-west, the evidence of this being that grooves larger and deeper than others passed away from small indentations, which may have been the impressions of pebbles, in a north-west direction.

In 1872 †† Mr. Mellard Reade, C.E., F.G.S., described cross striæ at Bootle, running E.N.E. and N. 22° W., and advocated the hypothesis of ice-sheets moving from the mountains of Wales and Cumberland respectively. In the same year ‡‡ striæ at Great Crosby, bearing N. 40° W., and in 1876§§ others at Little Crosby, bearing N. 22° W., were discovered by the same observer; and in the following year striæ at Tranmere and Oxtton, having the direction N. 40° W. and N.N.W., were recorded by Dr. Ricketts, who, opposing the hypothesis of the Irish Sea having been occupied by an ice-sheet, attributed the

* Proc. Lit. & Phil. Soc. Liverpool, session 1859-60.

† Trans. Manchester Geol. Soc. vol. iv. p. 288.

‡ Quart. Journ. Geol. Soc. vol. xviii. p. 377, and Proc. Liverpool Geol. Soc. sess. 3, 1861-62.

§ Proc. Liverpool Geol. Soc. sess. 3, 1861-62 (footnote).

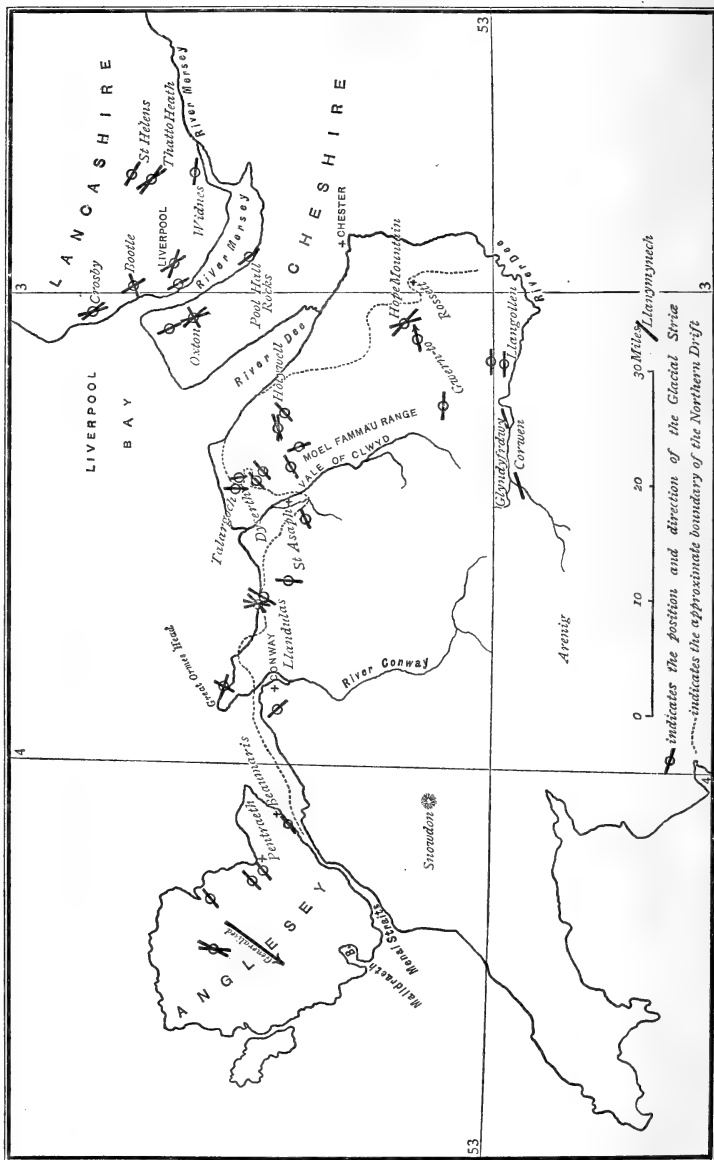
|| *Ibid.* sess. 8, 1866-67.

¶ 'Report of the British Association' for 1870.

** Proc. Liverpool Geol. Soc. sess. 11, 1869-70.

†† *Ibid.* sess. 41, 1872-73. ‡‡ *Op. cit.* §§ *Ibid.* sess. 18, 1876-77.

Fig. 1.—Map of South Lancashire, Cheshire, and the Welsh Border, showing positions and directions of Glacial Striae.



indicates the position and direction of the Glacial Striae
 indicates the approximate boundary of the Northern Drift

markings to glaciers descending the valleys. In the same year (1877), Mr. Morton * published a complete list of all the striæ known up to that time, and after considering the divergence of direction over a small area, and the partial occurrence of striated surfaces, rejected the land-ice theory in favour of drifting field-ice carried by tidal currents. In this year also † I observed striæ in the neighbourhood of St. Helens bearing W. 30° N. and W. 33° N., and in four instances near Widnes bearing W. 8° N.; as also a remarkable striated surface at the Pool Hall Rocks, near Ellesmere Port, between tide-marks, where the striæ ran N. 43° W.

Omitting the cross striations observed at Bootle and Flaybrick Hill, the above-named scratches (see Map, fig. 1) show an approximate parallelism. Those in the immediate neighbourhood of Liverpool and Birkenhead, forming a group of fourteen in number (not including the single oblique groove observed by Mr. Morton in North Hill Street ‡), have an average direction of N. 28° W., with an extreme variation of 27°. A line drawn in this direction through Liverpool would pass about halfway between the coast of Cumberland and the Isle of Man, and coincide approximately with the direction of the channel of the Mersey at Liverpool.

The Pool Hall striæ also coincide in direction with the river, which here begins to bend to the east; and the same observation may be made with regard to the striæ about Widnes. They were no doubt influenced in their direction by the Keuper-Sandstone hills, which rise abruptly from the plain on the south side of the valley of the Mersey. But as the same tendency to a deflection towards the east is shown at Thatto Heath and St. Helens, though to a less degree, there would appear to be a general change in the direction of the glaciation, independently of local causes of deflection, from N. 20°–30° W. in Liverpool to about N.W. further inland. It may here be remarked that striæ have been observed at Manchester running N. 40° W. §

Two cases only of striations having a totally different direction have been observed near Liverpool—in one case at Bootle, running E.N.E., by Mr. Reade, and in the other at Flaybrick Hill, Birkenhead, running E. 30° N., by Mr. Mackintosh. A line drawn through Liverpool in the mean direction of these striæ passes nearly through Snowdon, and is almost exactly at right angles to the mean direction of the first-described set.

In the diagram, fig. 2 (p. 372), the whole of the striæ described above are represented in their true directions; the preponderance of those in the north-west quarter of the compass and the general parallelism of those in the immediate neighbourhood of Liverpool are sufficiently obvious.

There is unfortunately very little evidence afforded by the appearance of the scratches themselves as to whether the glaciation

* Proc. Liverpool Geol. Soc. sess. 18, 1876–77.

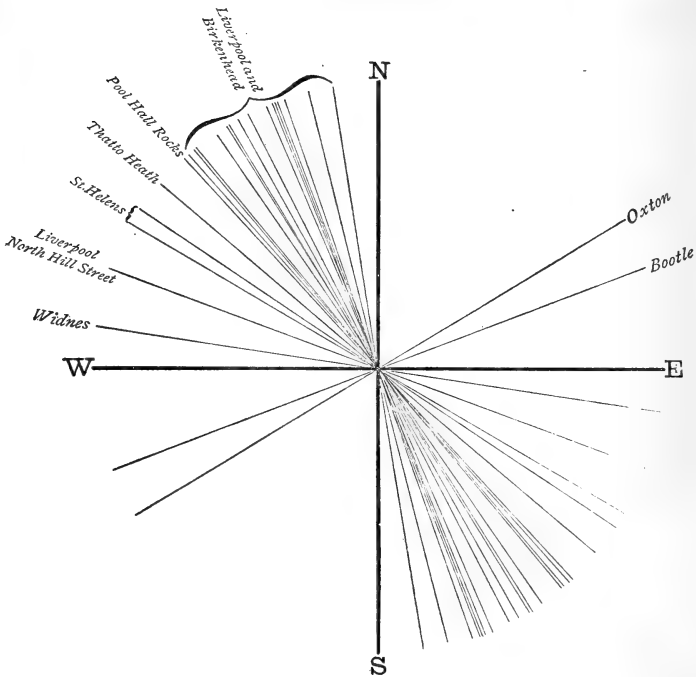
† Geol. Survey Memoir, 'On the Superficial Deposits of S.W. Lancashire,' p. 47.

‡ Proc. Liverpool Geol. Soc. sess. 18, 1876–77.

§ J. Plant, Trans. Geol. Soc. Manchester, vol. vi.

was effected from the north-west or from the south-east. In some cases it has been noticed that pebbles half imbedded in the rock are bruised on those sides which face the south-east, apparently through

Fig. 2.—Diagram showing directions of Striæ in South Lancashire and Cheshire.



having been opposed to the ice, as mentioned by Mr. Morton*. Dr. Ricketts, as previously stated, inferred from the nature of the groovings that this was the direction at Thatto Heath. On the other hand, Mr. Mellard Reade refers to a rubble of local rocks which had apparently been pushed by a force acting from the N.N.W. In the case of the cross striæ at Bootle, Mr. Reade inferred from the outline of the rock that the movement had been from the west.

I was not able in any of the striæ I observed to find evidence bearing on this point, but I noticed terminal curvature in several places, that is to say the bending back of strata at their outcrop as if by pressure†. In all cases in the Mersey valley the bending back was from the north-west, and was independent of the local configuration of the ground. A similar observation was

* 'British Association Report' for 1870.

† "Geology of Prescott" (Geol. Survey Memoir), 3rd edition, figs. 7, 8, & 9, and "Geology of Chester" (Geol. Survey Memoir), p. 30, fig. 8.

made by Mr. James Eccles on the outcrops of some Carboniferous strata near Blackburn *. In this case also the dragging over of the edges of the beds was to the S.S.E.

While, however, this doubt exists in the case of the striæ, the fact of the materials of which the drift of South Lancashire and Cheshire is composed having travelled in a S.S.E. direction is capable of easy proof. The greater number of the boulders have been derived from the Lake District, and are imbedded with fragments of, and in a matrix derived from, the Carboniferous and Triassic rocks of Lancashire; they are accompanied, in smaller quantities, by Scotch granitic rocks, and by flints and hardened chalk from the north of Ireland †. Southwards, *i. e.* on receding from the source of supply, the boulders become fewer in number and the clay more homogeneous. At the same time, on passing southwards from the Lancashire Coal-field on to the Triassic area of Cheshire, the red tinge of the Boulder-clay becomes steadily stronger. So gradual, however, are these changes that it is only by comparing distant localities that they can be fully realized.

The sands and gravels provide further evidence of the existence of currents flowing from the N.N.W. These deposits, which usually underlie Boulder-clay, in certain areas rise to the surface in mounds or long banks, throwing off the Boulder-clay on either side, and running for two or three miles across the plain ‡. While from their form, and in their composition of stratified beds of sand and shingle with shell-fragments, these banks are clearly the result of marine currents, from their direction, and by the fact of their frequently starting from the south-east side of a hill, they show that those currents flowed from the N.N.W. Nor is there any evidence in the drifts of South Lancashire and Cheshire of there ever having been much variation from this direction; for the percentage of boulders and the composition of the drifts are very similar from top to bottom, nor is it possible to detect any such marked differences between the upper and lower beds as to make the application of such names as the Upper or the Lower Boulder-clay possible. Thus the direction in which the drift has been transported agrees with that in which the edges of the outcropping beds have been forced, and with the prevalent direction of the glacial striæ. The two former having been exclusively in a south-south-easterly direction, it seems extremely probable that the striating agent moved in this direction also.

Lastly, it is almost invariably under Boulder-clay that the rock has been found to be striated. Though the sands and gravels are included among the glacial deposits, the Boulder-clays alone show direct evidence of the action of ice. In them alone are found scratched stones, even in the smaller masses included or interbedded in the sand; and though sometimes rudely stratified, they are usually

* Trans. Geol. Soc. Manchester, vol. vii. p. 20.

† Mackintosh, "Results of a . . . Survey . . . of the Erratic Blocks . . . of the West of England and East of Wales," Quart. Journ. Geol. Soc. vol. xxxv. p. 425 (1879).

‡ "Geology of Chester" (Geol. Survey Memoir), p. 16 (1882).

devoid of such lamination as is shown by clays deposited freely in water, and thus present a strong contrast with the beds of laminated clay or loam which sometimes accompany the sands and gravels. The Boulder-clays moreover contain twisted lenticular beds and pockets of sand, the latter probably being disconnected portions of a jumbled-up bed of sand. This mechanical disturbance is often shared by the bed upon which a Boulder-clay rests, whether of sand or rock: in the former case, the veins of loam and grit are displaced, or so mixed up that the bedding is obliterated; in the latter case the more flexible strata are often bent, or the harder ones striated. It seems, then, that not only is there a correspondence in the direction of the drift-transportal and that of the striæ, but that the latter, themselves the direct work of ice, are found only in conjunction with those beds of the drift which contain evidence of ice-action. On these grounds alone there would be a strong presumption that the same agent produced the striæ that distributed the Boulder-clay. This presumption is strengthened by the fact that I shall now bring forward, that the striæ in the neighbouring borders of Wales, while showing an entirely different prevalent direction, yet maintain the same connexion with the associated drift-deposits.

PART II.

The Welsh Border.

The general parallelism exhibited by the striæ of Liverpool is less observable in those of the North-Wales border, probably through their direction having been in many instances locally influenced by the more pronounced configuration of the ground. But though for this reason less importance must be attached to individual striæ, it is equally possible to generalize from a large number. It may be stated that the N.N.W. direction, so common about Liverpool, is exceptional in the neighbouring parts of Wales, while the E.N.E. direction observed in two instances only near Liverpool becomes the prevalent direction on crossing the border.

The locality nearest to Liverpool in which striæ have been observed is on Pen-y-ball, near Holywell*, where they run N. 35° E. and N. 40° E. At Pen-y-gelli they run E. and W., and E. 15° N. On Cwm mountain the direction of striæ, as observed by Mr. Tiddeman, is N.E. and E. 33° N., or E. 10° N. where observed by Prof. Hughes; while on Moel Hyraddug they are N.E. The striæ in these localities range from 600 to 1000 ft. above the sea, and show an approximate parallelism; they give an average direction of E. 35° N., and thus agree closely with the cross striæ at Liverpool, which run E. 22° N. and E. 30° N.

Further south, I have observed striæ running E. 18° N. at an elevation of 1100 feet on Gwern-to, a hill on the north side of the

* First observed by Mr. G. W. Shrubsole, F.G.S. (see Morton, Proc. Liverpool Geol. Soc. sess. 17, 1875-76).

great Bala fault near Minera. The projecting quartz pebbles are splintered on those sides which face the west, and have small ridges running towards the east, as though the glaciation had taken place from the west. At three miles distance, on Hope Mountain, there are striæ running nearly at right angles to those of Gwern-to, their direction being N. 15° W., at a height of 530 feet above the sea. Mr. Mackintosh* mentions striæ in this locality bearing N.W., but notices that at Corwen and Glyndyfrdwy they run from the W.S.W. The same direction has been observed in this locality by Prof. Hughes, who has also remarked striæ at Bryngorlan at the south end of the vale of Clwyd, ranging from a little north to a little south of east. In the Vale of Llangollen and on the high ground forming its north side striæ are stated by Mr. Morton † to run east and west at an elevation of 1200 feet, and at Llan-y-mynech to run N.E. and S.W. It will be noticed that all the striæ referred to above, excepting those on Hope Mountain, fall into the N.E. quarter of the compass. Those on Hope Mountain, on the other hand, together with some at Hawarden recently noticed by Mr. De Rance, coincide very closely with the direction of the main glaciation of Liverpool.

Returning to the north, striæ are found near Gwaenysgor, in the same neighbourhood as those of Moel Hyraddug, and also at a high elevation (viz. 660 feet), but running N. 5° W.; and again at the foot of a steep rocky cliff called Craig Fawr, overhanging the Talargoch mine, and facing west, there occur striæ running horizontally round a projecting shoulder of limestone towards the south, the direction in this case being indicated by the fact that the north sides only of the prominences of the rock are striated. In these two instances also the striæ appear to coincide with the principal set of Liverpool.

Two other instances have been observed in this district, namely at Rhuallt, near St. Asaph, where the striæ run W. 27° S., and in the Coed-nant-y-wrach, near Caerwys, where they run N. 20° W.; but in both cases the direction of the striæ has been determined by that of the deep and narrow ravines in which they are situated.

On the west side of the Vale of Clwyd, they have been noticed by Prof. Hughes at Cefn, near St. Asaph, with the direction E.N.E.; and proceeding along the coast westwards, we find them in several spots near Llandulas. They have been observed by Mr. Tiddeman in the valley of the Dulas, on the N.W. spur of Cefn-yr-ogof, to run N. 12° E., and on the nearly level plateau above the limestone cliff over the station I found them pointing N.E. and N. 30° E. The brow of limestone forming the eastern entrance to the Craig (or Penmaen) tunnel is glaciated in a direction N. 10° W., and on the point above the tunnel they run N. 10° E. In the two last-named cases the striæ occur on nearly vertical rock-faces, the precise direction therefore depending upon that of the cliff.

At the Great Ormes Head the striæ run horizontally along, and straight down, a steep slope facing south-east, so as to cross obliquely

* Quart. Journ. Geol. Soc. vol. xxx. 1874.

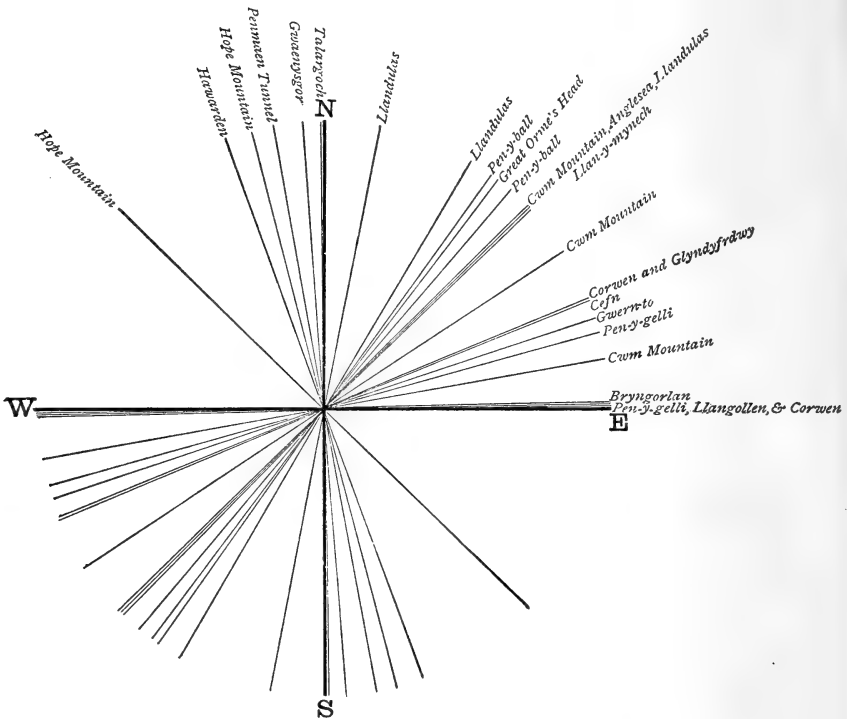
† Proc. Liverpool Geol. Soc. sess. 17, 1875-76.

with the directions N. 26° E. and E. 20° S. They are found again in the Sychnant Pass, west of Conway, running S.E.; but their direction here has probably been determined by the form of the ground.

Lastly the prevalent direction of the striæ of Anglesey has been observed by Sir Andrew Ramsay * as being N. 30°–40° E. Striæ having the direction N. 45° E. have been observed by Mr. Morton near Pentraeth †, and others may be observed on the shores of the Menai Straits, near Beaumaris, as pointed out to me by Sir Andrew Ramsay. Dr. Ricketts also refers to striæ at Llanerchymedd having “a direction towards S. 10° W. and curving round a boss of rock to S. 20° W.” ‡

In the diagram forming fig. 3 the striæ of Coed-y-nant, Rhuallt,

Fig. 3.—Diagram showing direction of Striæ on the Welsh Border.



and Sychnant, and one of those at the Great Ormes Head have been omitted. In the first two cases certainly, and in the third probably,

* “How Anglesey became an Island,” *Quart. Journ. Geol. Soc.* xxxii. p. 116 (1876).

† *Proc. Liverpool Geol. Soc.* sess. 17, 1875–76.

‡ *Ibid.* sess. 18, 1876–77.

the direction has been determined by that of the valleys in which they occur, while those which run straight down the slope on the Ormes Head are probably due to the local action of gravitation. Omitting these doubtful cases, it will be seen that along the east border of Wales there is a very marked parallelism among the striæ in a general east-north-east direction. Out of the whole number observed in this part of the district, five only occur in that quarter of the compass in which the Liverpool striæ are so thickly grouped, those, namely, of Talargoch, Gwaenysgor, Penmaen, Hope Mountain, and Hawarden; and all these occur on the outskirts of the Welsh drift-area. The remainder, as I shall presently show, agree in direction with the drift-transportal of the area in which they are situated. The horizontal striæ of the Great Ormes Head, though approximately parallel to these, belong more probably to the Anglesey system of glaciation, and were produced by ice from the north. Those of Llandulas are more doubtful: from their contiguity and parallelism they were probably produced by the same agent; but situated, as they are, close to the boundary, and agreeing in direction more or less with both the Flintshire and the Anglesey systems, it is difficult to assign them to either with any degree of certainty.

This change in the direction of the striæ which takes place on crossing the Welsh border is accompanied, as before stated, by a corresponding change in the nature of the drift, the general arrangement of the beds remaining the same, but the materials showing clearly a transportation from the west and south-west. The boundary of the Cheshire and Lancashire type of drift with its northern derivatives is shown on the accompanying map (p. 370). It runs from the Menai Straits by Llandulas to the Vale of Clwyd, nearly coinciding with the coast, but bending southwards so as to include the low ground bordering the coasts at the Ormes Head, Colwyn Bay, and Llandulas, and the northern part of the Vale of Clwyd. Rounding Cwm Mountain, the northernmost point of the Moel Famau range of Silurian rocks, the boundary then bends sharply up the narrow valley occupied by the Dyserth stream, so as to include a portion of the high ground formed by the Carboniferous Limestone. Northwards it once more follows the hill-foot by Talargoch and Prestatyn, to Gronant, whence bending southwards it runs through Flintshire, rising in places to some of the high ground formed by the Carboniferous-Limestone escarpment. West of Chester also, the rise from the plain to the hills being gradual, the boundary runs up to a comparatively high level, so as to pass within a mile of Hope Mountain. Thence it doubles back to Rossett, and so once more southward.

Along portions of this line the northern drift is banked up against a steep inland cliff as at the Ormes Head, Llandulas, Talargoch, and Prestatyn, this cliff being, in all probability, a pre-glacial coast-line. In such situations the northern drift is found to overlies the drift of local origin, presenting in its comparatively stoneless homogeneous condition a strong contrast to the intensely stony local deposits. In other places, as at Rossett, the northern

drift thins out against an abrupt bank, forming the edge of a coarse gravel plateau of Welsh origin. As a general rule it may be stated that where there exists a strong physical feature between the hills and the plains, this feature, whether formed by drift or solid rock, will also form the limit of the northern drift. Where, on the other hand, the change of level is gradual, the limit of the northern drift runs to greater altitudes, and encroaches on the Principality.

The direction in which the drifts have been transported in the Welsh borders is in many cases easily ascertainable. The Coal-measures, Millstone Grit, Carboniferous Limestone, and Wenlock Shale of Flintshire form four roughly parallel belts of rocks of sufficiently marked lithological character to enable their detritus to be traced. In each case the drift-material has been transported approximately from south-west to north-east. The margin of the coal-field is overspread by débris from the Lower Carboniferous rocks; the Millstone-Grit area, as for example near Treiddyn, is thickly covered by a Boulder-clay crammed with great boulders of sandstone and limestone; while the limestone, especially in North Flintshire, near Caerwys and Cwm, is concealed beneath a yellow clay, packed with fragments of Wenlock Shale from the neighbouring Moel Fammau range. The distribution of red drift derived from the Bunter Sandstone of the Vale of Clwyd furnishes equally strong evidence. The bold and almost continuous barrier formed by the Moel Fammau range on the east side of the Vale of Clwyd is breached at Bodfari by the valley of the Wheeler, which is continued between the Silurian rocks and the Flintshire limestone escarpment by Caerwys, Nannerch, and Mold, until it becomes the valley of the Alyn, the valley itself, though occupied by different rivers in its different parts, forming a continuous breach through the successive hill-ranges. Up this valley the red débris of the Triassic rocks of the Vale of Clwyd has been transported in such masses, as to have led to the belief that the Trias itself ran up between the Wenlock-Shale hills. On both sides of the Wheeler, above Bodfari, the bright red sand mantles up the hill-sides or rises into eskers and mounds; and though the red tinge grows gradually fainter on receding from the Vale of Clwyd, it is not till the neighbourhood of Mold is reached that it is finally lost. The sections in the banks of the river near Caerwys and Nannerch show that this red sand is interstratified with a gravelly drift composed of fragments of Wenlock Shale from the Silurian hills. It should be noted, however, that a red drift-sand has been observed by Prof. Hughes in the gorge of the Elwy as far up as Dol*, which, if correctly identified as Clwydian drift, seems to have travelled in a westerly direction. It is possible that this part of the gorge came within the influence of the northerly currents by which drifts of northern derivation were spread over the lower part of the Vale of Clwyd.

The same story of easterly drift is told by the larger boulders

* Proc. Chester Soc. Nat. Sci. part 3 (1885).

which are plentifully distributed over the hills up to a height of nearly 1900 feet *. Though so many boulders of Flintshire limestone have been scattered over the Millstone Grit, I know of no instance in which they have travelled westwards on to the Wenlock-Shale area. One boulder of limestone has been noted on Moel Dywyll, at a height of about 1500 feet above the sea, but may be reasonably inferred to have been derived from the Carboniferous Limestone of the Vale of Clwyd. The vast majority of the erratic blocks have been derived from the felspathic igneous series of the Snowdon and Arenig range, while a large proportion of the remainder are attributable to the Denbighshire Grits.

The Carboniferous basement-beds, which form a narrow fringe on the south side of the limestone escarpment of Llandulas and Abergele, provide clear evidence of the direction of transport in this neighbourhood, inasmuch as the colour and lithological character of the pebbles of which they are composed renders them easily distinguishable from any other local rock. These pebbles are found to have travelled from the outcrop to the beach between Rhyl and Colwyn, that is in a northerly or north-easterly direction.

* A less marked instance occurs in the case of Bryn Eurian, an isolated hill of limestone on the west side of Colwyn Bay. The proportion of limestone boulders in the local Boulder-clay of the beach (the basement-clay) shows a marked increase at a point bearing N.N.E. from this hill. In the valley of the Dulas also it may be noted that though no limestone boulders have travelled on to the Wenlock-Shale area, yet the drift in the limestone gorge, as far north as Foel-fach, is composed exclusively of fragments of Wenlock Shale. Still further to the north, in this gorge, this Wenlock-Shale drift passes into a drift composed principally of limestone boulders, but containing some northern derivatives.

It would seem, from what has been said above, that the local drift of the country adjoining the north coast of Wales has travelled generally from the land towards the sea. The same remark, however, would not apply to the drift of Flintshire. In this part of North Wales the direction of transport was not towards the sea, though all the physical features of the ground run in such a direction as would appear likely to turn it in this direction, but was nearly at right angles to and across the principal ranges and valleys, namely the Moel Famau range, the Millstone-grit and Carboniferous-limestone escarpments, the Vale of Clwyd, and the Vale of Llanarmon. The fact of the transport having been towards the sea on the north coast, would seem to have been merely a geographical accident, the direction having been uniform along the whole border towards the east-north-east, and in other parts of the district independent of the physical configuration of the ground.

I have previously described the boundaries of the drift of northern derivation, and for the sake of clearness have indicated them by a dotted line on the accompanying map (p. 370). There is a tendency

* Mackintosh, *Quart. Journ. Geol. Soc.* xxxv. p. 425 (1879).

however, for the northern and the Welsh drifts to intermingle along this line. The ballast-pit at Colwyn Bay, for example, shows that the latest deposit of northern derivation, a reddish-brown clay with few boulders*, is jumbled up with a very stony and gravelly deposit, derived entirely from the waste of the Silurian hills by which the bay is enclosed. Similarly the underlying sands, which probably form part of the northern series of drifts, are interstratified with well-bedded gravels of Wenlock-Shale fragments †. These deposits rest upon an intensely hard and stony basement-clay, composed chiefly, if not entirely, of fragments of Welsh parentage, and extend but a short distance inland, the valleys leading up among the hills, containing a drift of purely local origin, which may or may not be continuous with the basement-clay of the coast. In the Vale of Clwyd also it is not possible to assign an exact southern limit to the drift of northern origin, the difficulty being here increased by the fact that both the far-travelled and the local drift are of a red colour. The occurrence of chalk flints, noted by Prof. Hughes as a characteristic feature of the drift about St. Asaph ‡, indicates that the currents from the north extended as far south at least as shown on the map. The most southerly boulder of Scotch granite noted by Mr. Mackintosh occurs about one mile south of Denbigh, on the Ruthin road §. In Flintshire, Criffel granite has been found by Mr. Mackintosh about a mile west of Mold, and Eskdale granite with chalk flints on Halkin Mountain, indicating that here also there is tendency for the northern drift to inosculate with the local deposit of western derivation.

As a general rule, however, the far-travelled drift is found to overlie that which is made up of the rocks nearer at hand. Thus the northern drift at Colwyn Bay, though mixed up with beds of local derivation, lies on the top of the almost purely local basement-clay. Again at Rossett the northern Boulder-clay of the low ground was clearly deposited after the great banks of local gravel at Gresford had come into existence.

As in the case of the Lancashire striæ, so in that of the Welsh, it is always a Boulder-clay or a gravelly deposit, corresponding in its want of stratification and in its containing scratched stones to a Boulder-clay, that is found to rest on the striated surfaces. The Boulder-clay on the Welsh border resembles that of the low grounds of Lancashire and Cheshire in being interstratified with sands and gravels, but differs from it in being very variable in composition; for it consists of Silurian, Carboniferous, or Triassic débris principally, according to local circumstances. There is, moreover, a less sharply marked distinction between Boulder-clay and gravel at the higher levels, the former, when made up of sandstone débris, seeming occa-

* The lower-level brown Boulder-clay of Mr. Mellard Reade: *Quart. Journ. Geol. Soc.* vol. xli. p. 104 (1885). See also Hall, "On the Geology of the district of Creuddyn," *Proc. Liverpool Geol. Soc.* (1867).

† *Geology of the Coasts adjoining Rhyl, Abergelae, and Colwyn* (Geol. Survey Memoir, 1885).

‡ *Proc. Chester Soc. Nat. Sci.*, part 3 (1885).

§ *Quart. Journ. Geol. Soc.* vol. xxxv. p. 432 (1879).

sionally to pass horizontally into gravel. Yet the essential characteristics of the two deposits are sufficiently preserved to make a broad separation possible—the sands and gravels consisting of water-worn stratified materials and rising into ridges and hummocks, while the Boulder-clay contains scratched stones, is scarcely or not at all bedded, and has a tendency to lie in hollows. The drifts of the two districts therefore, though lithologically different, are quite analogous in their arrangement, and are probably the result of a similar, if not the same, sequence of events.

As a general conclusion from the facts detailed above, it may be stated that:—

1. The striæ on the English and Welsh sides respectively, while showing variations among themselves, by a marked preponderance in one quarter of the compass, indicate a direction of principal glaciation, this direction being, on the English side from about N.N.W., and on the Welsh from about W.S.W.

2. The direction of glaciation in both districts agrees very closely with that of the transportation of the drift, but is only locally influenced by the form of the ground.

3. The striæ are by no means universal, but are found almost exclusively in connexion with those beds in the drift which contain evidence of the actual presence of ice.

PART III.

Origin of the Striæ.

Various theories have been put forward to account for the origin of the striæ in South Lancashire. Mr. Morton at first suggested the hypothesis of an ice-sheet moving from S.E. to N.W., but subsequently saw reason for abandoning this theory in favour of ice-fields carried by tidal currents*. Mr. Tiddeman, after describing the glaciation of North Lancashire, infers from the general parallelism that the striæ of North and South Lancashire were due to the same cause, this cause being the movement of an ice-sheet from N.N.W. to S.S.E.† Mr. Mellard Reade accounts for the cross striæ on the hypothesis of ice-sheets moving from the mountains of Cumberland and Wales respectively, and varying in relative power‡. Mr. De Rance attributes the glaciation to an ice-sheet moving southwards during the period of the Till, and before the submergence of the Boulder-clay period§. Sir Andrew Ramsay, in 1876, ascribed the glaciation of Anglesey and the scooping out of some shallow valleys to the grinding power of a vast glacier, moving from the

* Proc. Liverpool Geol. Soc. sess. 18, 1876-77.

† Quart. Journ. Geol. Soc. vol. xxviii. (1872).

‡ Proc. Liverpool Geol. Soc. sess. 14, 1872-73.

§ Geological Survey Memoir on the Superficial Deposits of S.W. Lancashire.

north-east across Morecambe and Liverpool Bays*. Dr. Ricketts, on the other hand, opposes the idea of "a monstrous glacier filling the Irish Sea, or of one extending from the mountains of Cumberland across the Bay of Liverpool," and attributes the scratches to glaciers descending the valleys. Mr. Mackintosh, in his numerous papers communicated to this Society, remarks on the fact that the striæ run in the main directions in which erratics have travelled from their respective points of dispersion, and attributes the dispersal of the erratics to floating ice. The production of the striæ also he assigns to the same agent, and remarks, "all the striated and planed rock-surfaces around Birkenhead and Liverpool are covered, so far as I have seen, by *Upper Boulder-clay* which, *without any change in its character* or intervening detritus, touches the striated rock-surfaces." He concludes that the overlying clay was deposited while the striated surface was still submerged †.

In 1883 Mr. Mellard Reade remarks that he has found no Shap granite on the west side of the Pennine chain, and that the erratic blocks are confined to the drainage-area of the Irish Sea. "This fact," he adds, "seems to me fatal to the idea of an ice-sheet overriding the great watersheds, and points to a system of glaciers radiating from mountain-nuclei. The distribution of the erratics, as described, seems unaccountable on any theory excepting that of their being sea-borne" ‡.

Prof. T. McK. Hughes notes the easterly direction of the striæ around the Vale of Clwyd, and points out that the ice ignored the vale. "Everything fits in with the hypothesis that the mixed Clwydian drift belongs to a period when the glacier ice had receded, and the sea was working away, sorting, and transporting the ancient glacial drift" §.

It is clear that neither in South Lancashire nor on the Welsh border can the phenomena have been produced by any system of local glaciation. A glacier formed in the valley of the Mersey would have taken exactly the opposite direction to that in which it is probable that the striating agent actually travelled; similarly a glacier formed in the Vale of Clwyd would certainly travel along the vale to the sea, down the uninterrupted slope of the Triassic rocks, rather than go out of its way to traverse the lofty Silurian hills on the west. Nor is there any trace of moraines in any of the valleys in the district under description. The question thus resolves itself into the consideration of two hypotheses,—first, that of two ice-sheets, anterior to the submergence, moving under the influence of gravitation from north-north-west in Lancashire, and from west-south-west in North Wales, and meeting at the border; secondly, that of field-

* "How Anglesey became an Island," *Quart. Journ. Geol. Soc.* vol. xxxii. (1876).

† *Quart. Journ. Geol. Soc.* vol. xxxv. p. 440 (1879).

‡ "The Drift-beds of the North-west of England and North Wales.—Part II.," *Quart. Journ. Geol. Soc.* vol. xxxix. p. 83 (1883).

§ *Proc. Chester Soc. Nat. Sci.* part 3 (1885).

or coast-ice carried by marine currents in these directions during the period of submergence.

The former of these hypotheses is opposed by the following facts:—

- (a) The rock surface is not *moutonnée* on a large scale, and striæ are by no means universal, but exceptional, even where Boulder-clay is still in existence. The terminal curvature, like the striæ, is of local occurrence.
- (b) The drifts associated with the striæ are marine deposits.
- (c) Striæ, inclined at various angles to one another, are found not only in the same neighbourhood, but upon the same slab.

(a) On the first of these points I may remark that though striæ are so abundant about Liverpool, and along the valley of the Mersey, they are at present entirely unknown near Chester, though the conditions for their preservation are precisely similar. This fact has been noted also by Mr. Mackintosh*. Within the Welsh border also it may be noticed that though striæ in some small areas are abundant, yet it is more common to find the rock-surface, even under undisturbed Boulder-clay, not only not striated, but presenting as ragged a surface as that of a limestone scar exposed to the air. It is, again, a well-known fact that the top of a lead-vein is frequently marked by the abundance of pebbles or masses of lead-ore in the drift. So abundant was this "gravel-ore" at Talargoch that the lower bed of the drift was tunnelled in search of it in all directions along the outcrop of the vein, at a depth of about 150–200 feet from the surface †. It is clear that these masses of galena are the residue of a considerable thickness of rock that has been removed, and that they have been left in consequence of their high specific gravity. This, however, would hardly have saved them from transportation had the district been crossed by an ice-sheet.

(b) On the marine origin of the drifts of the Lancashire and Cheshire plains and of the Welsh coast and border, there seems to be a general agreement of opinion ‡. The well-marked stratification of the deposits as a whole and the occurrence of marine shells throughout them seem to point to this conclusion. Though the stratification is scarcely apparent on an inspection of a Boulder-clay section, it becomes so on comparing the records of the great number of shafts and borings that have been made in South Lancashire and on the Welsh border. In every case where the drift attains any thickness, as in a preglacial river-valley or the maritime plain of North Flintshire and Denbighshire, it is found to consist of alternations of sheets of Boulder-clay with sand and gravel, the beds running sometimes for a mile or two without interruption. Thin beds of sand may be traced for hundreds of yards in the Boulder-clay, and even the Boulder-clay itself not unfrequently shows a rude separation into more or less stony bands. In one case (the

* Quart. Journ. Geol. Soc. vol. xxxv. p. 425 (1879).

† 'Geology of the Coast adjoining Rhyl, Abergel, and Colwyn' (Geological Survey Memoir, 1885), p. 47.

‡ This opinion is held also by Dr. Hicks. "On some Bone-caves in North Wales," Quart. Journ. Geol. Soc. vol. xlii. p. 16 (1886).

Railway-cutting at Spring's Branch, near Wigan) it consisted of a great number of alternating bands of red clay and fine sand, very regularly interstratified; in another (a brick-pit near Wigan) it was finely and evenly laminated. These, it is true, are exceptional forms of the Lancashire Boulder-clay, and I attach more importance to the fact of its occurring on a large scale in horizontal sheets alternating with sand and gravel as a proof of its being a stratified deposit.

One of the most noticeable features also in the drifts of the region under description is the great development of sand and gravel in which all evidence of ice-action is entirely wanting. The valley of the Weaver and of the Alyn and the Vale of Clwyd give examples in Wales, while in the neighbouring parts of England are found the great sand-banks of Ellesmere, Delamere, and other parts of Cheshire. Such extensive deposits of thoroughly washed and sorted sand and gravel are not found in the mountainous parts of Wales and the Lake District, where, on the other hand, the proofs of the former existence of an ice-sheet are more convincing. That they are part of the Glacial beds is clearly proved by the fact that in almost every case they may be seen to be overlain by true Boulder-clay*; and that they are truly marine deposits has, I believe, never been questioned †.

The question, however, on which disagreement exists is whether the striæ were produced before or during the submergence which led to the deposition of these marine beds.

The occurrence of a tough blue basement-clay packed with stones, most of which are scratched, underneath the undoubted marine drift of the Welsh coast has been previously noted. This "Till" ‡ has been attributed to the action of an ice-sheet passing northwards and eastwards from the highest ground of North Wales in a period preceding the submergence, and the striæ have been referred to the same agent.

The opinion of Mr. Mackintosh on this point has been already quoted (p. 382). My own observations also tend entirely to the conclusion that the striæ are connected with the marine drifts, and were formed during the submergence.

In almost every case it is the uppermost and newest member of the drift under which the striated rock-surfaces are found. From

* 'Geology of the Neighbourhood of Chester' (Geol. Survey Memoir).

† Sands and gravels with marine shells of recent species occur on Moel Tryfaen at a height of 1350 feet above the sea, on Minera Mountain at 1230 feet (Mackintosh, Quart. Journ. Geol. Soc. vol. xxxvii. 1881), and on Halkin Mountain at 956 feet. The total amount of submergence is estimated by Mr. Mackintosh to have been 1900 feet in North Wales (Proc. Chester Soc. Nat. Sci. part 3, 1885).

‡ The word "Till" has been usually applied to an unstratified clay in which boulders are very abundant, the name Boulder-clay being usually given to a less stony and more purely clayey deposit. A Boulder-clay, however, shades into a Till on approaching the source of the materials. The Chalky Boulder-clay of Lincolnshire, for example, becomes locally a chalk-till on the south side of the Lincolnshire Wolds. (Geol. Survey Memoir on sheet 83, in the press.) The relation between the Scotch Till and the Boulder-clay of the Lancashire plains has been discussed by Mr. Mellard Reade, Proc. Liverpool Geol. Soc. Session 21 (1879-80), and Trans. Geol. Soc. Glasgow, 1880.

the tendency of the drift to be in horizontal beds, filling up old valleys and hollows, it results that the upper beds frequently overlap the lower, and that towards the margin of a deeply drift-covered area, the newest member, usually a Boulder-clay, is found resting directly upon the rock. It is precisely in such situations that most of the striæ have been observed. But it is certain, from their freshness, even upon the friable Triassic sandstones, that they must have been covered immediately after they were produced, and must have remained so up to the present time. It follows, then, that they were formed after the earlier and before the latest of the marine deposits. From the general similarity from top to bottom presented by the whole series of the drift-beds in the plains *, it seems improbable that there can have been such complete breaks in the sequence of events as the repeated encroachments of an ice-sheet during the submergence of the area. There is less difficulty in conceiving, on the other hand, that the sea was subject to periodical invasions by floating ice, by the interruption of which the free sorting and stratification of sediment would be checked, and a sheet of Boulder-clay formed, while by the irregular drifting and occasional stranding of the ice, striæ, such as are observed, would be produced.

The evidence for the extension of a portion of the Lake-District ice-sheet as far south as North Lancashire has been given by Mr. Goodchild †, and consists in the position and general direction of the striæ and in the distribution of the drift, which he considers to have been carried in the ice.

The contiguous district on the south had been previously described by Mr. Tiddeman ‡, who states, as a result of his observations, that "the general movement was to the S. or S.S.E., across deep valleys and over hills of considerable elevation." He finds that the rock-surface is invariably *moutonnée* and usually striated where Till exists or has existed; that there are no indications of coasting or of deflection by partially submerged hills; that the terminal curvature is found on the flanks as well as on the tops of the hills; lastly, that the transportation of the Till is explicable only on the supposition that it was the *moraine profonde* of an ice-sheet. And for these reasons he attributes the observed effects to the action of an ice-sheet rather than of floating ice.

It will be seen, however, from what has been said above, that there are great differences between the region described by Mr. Tiddeman and that now under consideration, the principal being the comparative rarity of *moutonnées* or striated surfaces, and of terminal

* There is sometimes a larger proportion of local materials in the lower beds, as might be expected. So great, however, is the resemblance of one part of the series to another that the name of Upper and Lower Boulder-clay has been assigned to the same bed by different observers. It has not been found possible to make any general separation of Upper and Lower Boulder-clay in South Lancashire.

† Quart. Journ. Geol. Soc. vol. xxxi. (1875).

‡ *Ibid.* vol. xxviii. 1872.

curvature; but more especially the development of undoubtedly marine sands and gravels in association with Boulder-clays, probably of marine origin also.

But the view of this ice-sheet having extended from the north over this region and along the coast of North Wales has been put forward by Sir A. Ramsay as a result of his observations on the Isle of Anglesey *. The evidence adduced may be briefly stated as follows:—The gently undulating plain is overspread by detritus from the north; the underlying rocks are often ice-smoothed and marked with striæ pointing directly to the mountains of Cumberland; the Snowdon group of mountains sent down great glaciers to the west, north-west, and north, but never across the Menai Straits. The striations of Anglesey were produced by an ice-sheet which overspread the region now occupied by the shallow sea of Morecambe, Lancaster, and Liverpool Bays, and was of sufficient power to stop the encroachment of the Snowdon glaciers. Mall-draeth Marsh, the Menai Straits, and other valleys of minor note run in precisely the direction of the striæ, and were scooped out by this vast glacier from the north-east. It may be added that if the striation and configuration of Anglesey were produced by such an ice-sheet, it would form a strong argument for that of South Lancashire having been due to the same cause.

But I would venture to suggest that it is not necessary to invoke the assistance of this vast glacier to account for the form of the ground in Anglesey. In the case of both the Menai Straits and Mall-draeth Marsh large faults have introduced strips of Carboniferous strata among the older rocks; such faults invariably constitute lines of weakness, and the association of rocks so different as the Carboniferous (especially the Coal-measures) and highly altered schists invariably gives rise to a physical feature. These faults date from an early period, and features due to the structure, and corresponding more or less with those existing now, probably came into existence long before the Glacial period. The drifts of the island, as described, appear to be the continuation of those which overspread South Lancashire and fringe the coast of North Wales, and like them are probably marine. If, then, the features of the island are due to the geological structure and the drift is a marine deposit, the reasons for invoking the aid of an ice-sheet no longer exist.

While, however, there is a general agreement as to the marine origin of the sand, gravel, and associated Boulder-clays, there is an equally wide-spread opinion that the tough and very strong basement-clay, seen at Colwyn Bay, Bryn Elwy, Llanefydd, and other places in North Wales, is the product of an ice-sheet. It has been one of the objects of this paper to show that the striæ of the borderland belong to the later period of the undoubted marine drifts. So far as I know, none of those herein described show any connexion

* "How Anglesey became an Island," *Quart. Journ.-Geol. Soc.* vol. xxxii. (1876).

with the earlier deposit, except that, so far as can be judged from the very limited sections, the materials of which it is composed seem to have travelled also in a north-easterly direction. The discussion of its origin is therefore beyond the scope of this paper ; but it may be pointed out that the sequence of deposits presents a general similarity to that found in the east of England. The so-called Upper Boulder-clay, or Chalky Boulder-clay of Norfolk *, for example, with the underlying sands and gravels, is comparable in many ways to the marine drifts of South Lancashire and North Wales. In particular the signs of disturbance of the pre-existing beds, though not so marked as in the Contorted Drift of the east, are still a noticeable feature below a Boulder-clay in this district. The Cromer Till also, though consisting, of course, like the rest of the East Anglian drift, of different materials, corresponds in its description to the basement-clay of North Wales. Without entering into the question of contemporaneity in the deposits of the east and north-west of England, it may be remarked that a somewhat similar sequence of events is indicated in the two areas. The Cromer Till is usually regarded as the product of an ice-sheet, the sands and gravels as indicating an interglacial period of submergence, while the Upper or Chalky Boulder-clay is attributed by various authors to an ice-sheet or coast-ice.

The importance of the fact that the newer drifts of the north-west are made up of alternations of Boulder-clay and sand and gravel consists in this, that on the ice-sheet theory of the origin of the Boulder-clays, it must be supposed that either the sea-bed was repeatedly invaded by an ice-sheet, or that the land underwent repeated oscillations of level. In either case it would seem as if the beds and the evidence of each change should have been more widely spread. But nothing is more strongly impressed upon us by a careful drift-survey of this district than the impossibility of correlating the details of one section with those of another, unless in the immediate neighbourhood. The constantly varying conditions which seem to have prevailed, and the evidence of different conditions having held in neighbouring localities at the same time, seem to point to the action of floating ice driven by tidal or oceanic currents. During the time of even the greatest submergence Snowdon and the surrounding hills must have stood well above water, and on the south and south-east islands both large and small must have been numerous. By such a group the prevailing currents from the north would be deflected, to the south-west over Anglesey on the one side, and to the south-east over the plains of Cheshire and Shropshire on the other, while within the limits of the group a local circulation might be maintained.

* For a general account of the Norfolk Drifts, see "The Glacial Drift of Norfolk," by H. B. Woodward, Proc. Geol. Assoc. vol. ix. no. 3, p. 111 (1885).

Localities of Glacial Striae along the Coast and Border of North Wales.

Locality.	Direction.	Height above Ordnance datum.	Discoverer.	Where first described.
Pen-y-ball (near Holywell).....	{ N. 35° E. N. 40° E. E.	815	G. W. Shrubsole.	{ Proc. Liverpool Geol. Soc. 1875-76 and 1878-79.
Pen-y-gelli (near Holywell)	{ E. 15° N. E. 45° N. E. 33° N.	700	A. Strahan.	{ Ditto, 1878-79. Geology of the Coasts adjoining Rhyl, Abergel, and Colwyn (Geol. Surv. Mem.), p. 39.
Cwm Mountain (near Dyserth)	{ E. 10° N. E. 45° N. E. 18° N.	960	R. H. Tiddeman.	{ Proc. Chester Soc. Nat. Sci. pt. 3, p. 24 (1885).
Ditto	E. (about)	.....	T. M ^c K. Hughes.	{ Proc. Liverpool Geol. Soc. 1878-79. Not previously described.
Moel Hyraddug (near Dyserth)	E. 15° W.	750	A. Strahan.	{ Proc. Chester Soc. Nat. Sci. pt. 3, p. 24 (1885).
Gwevnto (near Minera)	N. 45° W.	1100	Ditto.	{ Not previously described.
Bryngorlan (south end of the Vale of Clwyd)	N. 20° W.	.....	T. M ^c K. Hughes.	{ Proc. Chester Soc. Nat. Sci. pt. 3, p. 24 (1885).
Hope Mountain	E. 22° N.	530	A. Strahan.	{ Not previously described.
Ditto	E. (a little N. of)	.....	D. Mackintosh.	{ Quart. Journ. Geol. Soc. xxx. 1879.
Bilberry Wood, Hawarden	E.	.....	C. E. De Rance.	{ Not previously described.
Corwen .....		.....	D. Mackintosh.	{ Quart. Journ. Geol. Soc. xxx. 1879.
Ditto (on Caer Drewen and near Nantbach) .....		.....	T. M ^c K. Hughes.	{ Proc. Chester Soc. Nat. Sci. pt. 3 (1885).
Glyndyfrdwy .....		.....	D. Mackintosh.	{ Quart. Journ. Geol. Soc. xxx. 1879.
Llangollen (below Pen-y-Caer) .....		.....	G. H. Morton.	{ Proc. Liverpool Geol. Soc. 1875-76.

Ditto (near top of Pen-y-Caer)				Proc. Liverpool Geol. Soc. 1875-76.
Llan-y-mynech				Ditto.
Gwachysgor (near Dyserth)	E. 45° N.	1200	G. H. Morton.	Ditto, 1878-79.
Craig Fawr (near Dyserth)	N. 5° W.	600	A. Strahan.	Ditto.
Rhuallt (near St. Asaph)	N.	660	Ditto.	Not previously described.
Coed-nant-y-wrach (near Caerwys)	E. 27° N.*	310	Ditto.	{ Proc. Chester Soc. Nat. Sci. pt. 3, p. 24 (1885).
Cefn (near St. Asaph)	N. 20° W.*	450	T. McK. Hughes.	{ Proc. Liverpool Geol. Soc. 1878-79.
Llandulas (above Craig Tunnel)	{ E. 22° N. N. 10° E. N. 45° E.	70	A. Strahan.	Ditto.
Ditto (east end of the Tunnel)	{ N. 10° W. N. 30° E.	130	Ditto.	{ Geology of the Coasts adjoining Rhyl, Abergele, and Colwyn (Geol. Surv. Mem.), p. 39.
Ditto (Quarry)		250	Ditto.	Proc. Liverpool Geol. Soc. 1878-79.
Ditto (Valley of the Dulais), near	N. 12° E.	230	R. H. Tiddeman.	
Great Ormes Head	{ N. 26° E.* E. 20° S.	50	A. Strahan.	Ditto.
Sychnant Pass (near Conway)	E. 45° S.*	300	Ditto.	Quart. Journ. Geol. Soc. xxxii. 1876.
Anglesey (in general)	N. 30°-40° E.	.....	Sir A. Ramsay.	Proc. Liverpool Geol. Soc. 1875-76.
Ditto (3 miles N.W. of Pentraeth)	N. 45° E.	.....	G. H. Morton.	Ditto.
Ditto (Tyddyn-bach)	N. 45° E.	.....	Ditto.	Ditto.
Ditto (Penrhos-lligwy)	N. 45° E.	.....	Ditto.	Ditto.
Ditto (S. side of Lligwy Bay)	N. 45° E.	.....	Dr. Ricketts.	Ditto, 1876-77.
Ditto (Llanerchymedd)	{ N. 10° E. N. 20° E.	.....	
Ditto (S.W. of Beaumaris)	N. 47° E.	18	Sir A. Ramsay.	

* Direction affected by local influences.

Localities of Glacial Striae in South Lancashire and Cheshire.
(Founded, with additions and corrections, on a list by Mr. Morton, Proc. Liverpool Geol. Soc. 1876-77.)

Locality.	Direction.	Height above Ordnance datum.	Discoverer.	Where first described.
Park Road, Liverpool	Loose blocks.			
North Hill Street, Liverpool	{ N. 35° W. W. 20° N.* }	160	G. H. Morton.	Proc. Liverpool Geol. Soc. 1876-77.
Boundary Street, Liverpool.....	N. 15° W.	80	Ditto.	Rep. Brit. Assoc. 1870.
Stanley Road, Liverpool	N. 15° W.	80	Ditto.	Quart. Journ. Geol. Soc. xviii. 1862.
Park Hill Road, Liverpool	N. 42° W.	120	Ditto.	Ditto.
Miller's Bridge, Bootle	{ N. 22° W. E. 22° N. }	90	T. M. Reade.	Proc. Liverpool Geol. Soc. 1872-73.
Christ's Church, Oxtou	N. 24° W.	100	R. Bostock.	Rep. Brit. Assoc. 1870.
Ditto	N. 22½° W.	105	Dr. Ricketts.	Proc. Liverpool Geol. Soc. 1876-77.
Ditto	N. 40° W.	62	Ditto.	Ditto.
Flaybrick Hill, Birkenhead.....	N. 30° W.	70	G. H. Morton.	Quart. Journ. Geol. Soc. xviii. 1862.
Ditto	N. 32° W.	170	Ditto.	Proc. Liverpool Geol. Soc. 1876-77.
Ditto	N. 20° W.	100	Ditto.	Ditto.
Wavertree	W. 30° S.	.....	D. Mackintosh.	Quart. Journ. Geol. Soc. xxxiii. 1877.
Crosby	N. 32° W.	170	G. H. Morton.	Rep. Brit. Assoc. 1870.
Little Crosby	N. 40° W.	25	T. M. Reade.	Proc. Liverpool Geol. Soc. 1873-74.
Thatto Heath	N. 22° W.	35	Ditto.	Ditto, 1876-77.
Pool Hall Rocks	W. 40° N.	290	Dr. Ricketts.	Ditto, 1869-70.
Farnworth Churchyard	N. 43° W.	6	A. Strahan.	Ditto, 1876-77.
Appleton, N.E. of	W. 8° N.	160	Ditto.	Geol. Survey Mem. S.W. Lancashire, 1876.
Appleton, S. of	W. 8° N.	90	Ditto.	Ditto.
Runcorn Gap, Bed of the Mersey	W. 8° N.	80	Ditto.	Geol. Survey Mem. Prescott (3rd ed.), 1882.
Runcorn, Bridgewater Company's Quarry	W. 8° N.	14	Ditto.	Geol. Survey Mem. S.W. Lancashire, 1876.
Crank, St. Helens.....	W.N.W.†	.....	Ditto.	Proc. Liverpool Geol. Soc. 1876-77.
St. Helens, Middlehurst's Delf	W. 30° N.	.....	Ditto.	Ditto.
Garswood, near St. Helens	W. 33° N.	.....	Ditto.	Geol. Survey Mem. S.W. Lancashire, 1876.
	W. 30° N.	.....	Ditto.	Ditto.

* A single groove.

† By information. See Proc. Liverpool Geol. Soc. 1876-77.

† By information.

DISCUSSION.

The PRESIDENT observed that the Author had made good use of his opportunities as geological surveyor in the district, and had brought forward facts which seemed to be of great value in their bearing upon the two rival theories of glaciation.

Mr. DE RANCE said that he had read a paper sixteen years ago on the same district, and was glad to find that Mr. Strahan's results agreed with his conclusions.

He proposed to enlarge on a few points. He noticed, for instance, that many of the old villages were built on those little sandy and gravelly knolls which come up through the Boulder-clay. It might be true that the sands and gravels were not so abundant in South Lancashire as on the Welsh border, but in the neighbourhood of Blackpool there are splendid sections showing two Boulder-clays and a gravel series. When false-bedded the direction is S.S.E.

As regards the discovery of flints in Boulder-clays, he mentioned that in the neighbourhood of Blackpool Lias fossils, evidently from Antrim, had been found in Middle Glacial gravels. All these clays contained shells of the same species, but more broken than those in the gravels.

Dr. HICKS had examined portions of the district referred to, and held the same opinion as the Author as to the origin of the striæ. In the caverns examined by him there was at the base a local drift, then marine sands, and above all a Boulder-clay with ice-scratched boulders from northern sources.

The AUTHOR thanked the Society for the reception accorded to his paper.

33. *On some ERUPTIVE ROCKS from the NEIGHBOURHOOD of St. MINVER, CORNWALL.* By FRANK RUTLEY, Esq., Lecturer on Mineralogy in the Royal School of Mines. (Read June 9, 1886.)

[PLATE XII.]

AMONG the numerous exposures of eruptive rock occurring in the vicinity of St. Minver, near Padstow, those at Cant Hill and Carlion are conspicuously represented on Sheet 30 of the Geological Survey map.

In both cases these rocks occupy high ground, and in both they are mapped as "greenstone;" but a casual glance suffices to show that they are very different from one another, although at their nearest points they are little more than half a mile apart.

The surface of the ground is undulating, and the hills are, as a rule, smooth and under cultivation, so that it seems probable that the boundary lines of these eruptive rocks have been partly mapped from superficial features, the exposures being neither large nor numerous. If it were not for two or three small quarries which have been opened, there would be very little eruptive rock visible, and in no case did I see any contact with the adjacent slates. I am therefore unable to state what is the relation which the former bears to the latter, although, from an inspection of the Survey map, I hoped that it would have been possible to gain some information upon this point at the base of Cant Hill, on the eastern side.

With this object in view I examined the foot of the hill, passing from St. Michael along the bank of the estuary to the small cove near Cant Farm, but, at the spot where, judging from the map, the eruptive rock might be expected to be visible in place, nothing but loose fragments of it were to be seen. The journey round the base of the hill being dependent on the tide, and the time at my disposal being limited, it seemed scarcely worth while to repeat the visit; but it is just possible that more diligent search, hereabout, might afford useful information.

The impression which I first received, on examining sections of the Cant-Hill rocks microscopically, was that they were tuffs composed of basic lavas and fragments of vesicular glassy rock; but Prof. Renard, to whom I forwarded the sections, having kindly examined them, favoured me with his opinion that they were vitreous lavas of a diabasic type, and, after much time spent in further examination of them, I have arrived at a similar conclusion. My thanks are therefore largely due to Prof. Renard for his useful suggestion. I am, however, still not fully satisfied that the elastic appearances visible in some of these rocks may not be due to the presence of volcanic ejectamenta, although it is also possible that these appearances might result from the crushing of a lava by the pressure of superincumbent masses. And here another difficulty steps in, for we sometimes meet with beds of volcanic ejecta

consisting of identical or unmixed lava fragments, in which case it is hard to distinguish such a deposit from a similar coulée of lava which has undergone crushing *in situ*.

To Mr. Grenville Cole, whose knowledge of vitreous rocks is both extensive and exact, I am also indebted for a confirmatory opinion*.

The following is a short account of the nature of these rocks:—

No. 1. *Cant Hill, East end, at top of hill* (Plate XII. fig. 1).—This is a light brown, roughly fissile rock with greyish or yellowish-white porphyritic crystals, chiefly less than an eighth of an inch in diameter. On a surface cut transversely to the direction of fission, the general structure of the rock is rendered apparent by exceedingly delicate sinuous streaks of three kinds, namely dark green, reddish-brown, and grey. These fine streaks are seen here and there to be traversed by very delicate veins of a dark-green colour.

Under the microscope the finely-streaked appearance of the section is at first sight strongly suggestive of the fluxion structure seen in lavas. There are bands and small knots of felsitic matter (micro-crystalline) separated by bands of translucent greenish-yellow or brownish-yellow serpentine †, and more delicate opaque streaks, some of which are reddish brown or rust-coloured, while others appear snow-white. These opaque streaks seem to indicate, in part, an original fluxion-structure in the rock, especially in the case of the snow-white markings. In one part of this section there occurs a thin vein of greenish-yellow to brownish-yellow serpentine, which is traversed by the opaque rust-coloured strings, while the opaque white streaks are distinctly separated by the vein ending abruptly against its edges. This clearly shows that we have to deal with two distinct sets of opaque streaks—the one set having been formed before, and the other after the formation of the vein. The white streaks represent the earlier and the rust-coloured streaks the later structures. That the rust-coloured markings do not represent fluxion-structure is evident, since, if they did, they would be interrupted by the vein of serpentine; but they traverse it. The white markings, on the other hand, do not cross the serpentine vein, and it is therefore possible that they indicate an original fluxion-structure in the rock. Both sets of these opaque strings run confusedly together, and interlace in a complicated network, except where the vein occurs.

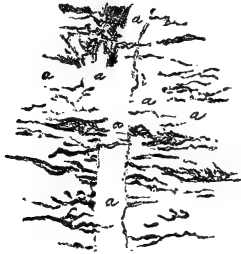
The greenish-yellow serpentinous films and strings which follow the general striping of the section are found, when examined in polarized light, to be actually continuous with the similar substance of the vein which traverses them, as shown at *aa* in the accompanying woodcut (fig. 1), while the black markings indicate the opaque

* Shortly before the reading of this paper Prof. Bonney also examined these specimens and sections, and kindly gave me his opinions on them. In the main his conclusions agreed with those already arrived at. One or two of the points upon which he differed have since been recorded in supplementary notes.

† Prof. Bonney, who favoured me with an opinion upon these sections, regards much of the substance which I have here called serpentine as a palagonitic material.

strings, some of which (opaque white) are cut off by, while others (rusty-coloured) traverse the vein.

Fig. 1.—*Cant Hill, East end, at top of hill.*



a a. Greenish-yellow to brownish-yellow scaly serpentinous matter.

The sketch shows the continuity of bands of this serpentinous substance with the cross vein of the same material. In the vein the scaly character is better seen than in the bands, since in the vein the scales lie confusedly in all directions, while in the bands they are approximately parallel.

In the felsitic portions of the preparation numerous small circular and lenticular spaces occur, filled sometimes with quartz and at others with serpentine. These have apparently been vesicles, and from these, and from the appearance of fluxion-structure, there seems little doubt that the rock was originally a lava. In one or two places there seems to be evidence of a banded, and perhaps spherulitic structure, as shown in the middle of fig. 1, Plate XII. We have now advanced far enough in our examination to assume that we are dealing with a banded vesicular lava. The next point to ascertain is the nature of the assumed lava.

Porphyritic feldspars are present in tolerable quantity, but they are often considerably altered. Where they are sufficiently fresh to exhibit distinct optical properties they are seen, from their extinctions, to be triclinic, the extinction-angles often approximating to those of labradorite. The next point of interest is the profusion of serpentine which is present in the rock. It occurs chiefly in irregular or lenticular patches which fade away into filaments, granular specks, or stains. The general appearance, however, is that of very irregular bands, and it seems probable that their more expanded portions represent pseudomorphs after pyroxene or olivine which have been reduced to lenticular forms by pressure. The opaque rusty-coloured matter in the rock is limonite; the opaque white substance kaolin, or perhaps leucoxene in part. We have therefore, with the exception of a few imperfectly altered crystals of triclinic feldspar, nothing but decomposition-products. If from these secondary materials we endeavour to speculate on the original mineral constitution of the rock, we have triclinic feldspar (labradorite

in part) and its secondary products kaolin and felsitic matter, the secondary product serpentine, which has probably resulted from the decomposition of pyroxene or olivine, and the secondary product limonite, which may have been derived from the alteration of magnetite or ilmenite. The normal constituents of the rock may therefore be regarded as those of a basalt or an andesite, while the greater part of the felsitic matter present most likely represents the alteration of a glassy base. We therefore seem justified in regarding this rock as a once vitreous lava of a more or less basic type. To some extent I feel confirmed in this view by remarks made by Professor Renard, who kindly examined these sections and gave me the benefit of his "impressions" concerning them; and, although I had previously arrived at similar conclusions regarding the mineral constitution of these rocks, I must admit that I was inclined to regard them as tuffs composed of fragments of once vitreous basic lavas, rather than true coherent lava-flows. As it is, I cannot help thinking that they have in many cases experienced considerable crushing; but, if so, it has been from pressure normal to the planes of foliation, and the foliation is due, first to decomposition of certain mineral constituents, and secondly to pressure; but I can find no evidence that any shearing action has been implicated in the production of the structure which now exists in the rock. The evidence afforded by the small serpentine veins transverse to the direction of foliation negatives such a supposition.

No. 2. *Cant Hill, East end, at top of hill* (Plate XII. fig. 3).—This specimen was collected from the same locality as no. 1, in a small grubbing not more than four or five feet deep. It is a pale greenish-brown or greenish-grey rock, with numerous pale grey or yellowish-white porphyritic crystals or flecks ranging from about a fifth of an inch to quite microscopical dimensions.

On a smoothly cut surface very delicate, wavy, but roughly parallel streaks of a dark green colour are visible. A vein of a dark green serpentinous substance cuts obliquely across the banding in this specimen. The green matter has a hardness of about 3 or slightly less. The rock weathers with a rusty brown surface.

Under the microscope it presents the appearance of a vesicular lava with a more or less devitrified ground-mass, and contains numerous porphyritic triclinic felspar crystals, which have frequently a fragmentary aspect. The vesicles are extremely numerous, in most cases their sections are circles or ellipses, although they are sometimes of irregular form, and they are for the most part filled with serpentine, chaledony, or quartz. The section is impregnated with much opaque, yellowish-white matter, apparently kaolin. A drawing made from this preparation, as seen by ordinary transmitted light under an amplification of 25 diameters, is shown in fig. 3, Plate XII. There is, in many parts of this section, an appearance of contorted fluxion-structure. The extinction-angles of some of the porphyritic felspar crystals indicate labradorite, others anorthite. Some of these seem to have undergone a certain amount of corrosion, as suggested by Prof. Renard.

No. 3. *Cant Hill, West end, at top of hill* (Plate XII. fig. 2).—This is a purplish-grey rock with a somewhat fissile structure and little greyish-white specks of irregular form. It was derived from a small quarry which has been opened out on the top of the hill. The rock in this quarry is strongly jointed, and appears to be fresher than that occurring in the small grubbing from which the specimens nos. 1 and 2 were procured. The stone here still seems, however, to be considerably weathered*. A section of this rock seen under the microscope appears as a clear, almost colourless, glassy lava full of small vesicles, frequently bordered by minute round granules or moniliform edgings of an opaque snow-white substance. The glassy matter also contains irregular nests, strings, and nebulous segregations of minute yellowish-green granules, which appear to be epidote (fig. 2, Plate XII.) The vesicles give circular and elliptical sections in some places, while in others they are greatly elongated in uniform directions, sometimes occurring close together, so as to form vesicular streams, which are frequently sinuous and indicate fluxion. There is also a wavy, thread-like structure in the glass, which is not very clearly to be recognized except between crossed nicols under a moderately high power, when the fibres are seen to depolarize in feeble greyish-blue tints. At first sight it would seem that this substance might be serpentine, but it is probably a felsitic substance ("microfelsitic basis" of Rosenbusch). In many places the glass is almost unaltered. Small crystals of triclinic felspar occur in this glassy or once glassy ground-mass. The rock appears to have been somewhat crushed, and contains a considerable amount of calcite, a little quartz, and a few dark opaque grains, which are either magnetite or titaniferous iron; possibly there is a little serpentine. Much of the opaque white or faintly rusty-stained matter in the section I am inclined to regard as leucoxene, resulting from the complete decomposition of ilmenite. We have here, then, a partially devitrified lava of a highly vesicular character, in which the felspars are triclinic, while the secondary products, epidote and leucoxene, indicate that pyroxene, possibly olivine, and ilmenite were once present as original constituents. The rock, therefore, may be assumed to have been a vitreous basic lava, and may very likely be coeval with the lavas erupted in the Brent-Tor district, which, although mapped as occurring in the Culm series, are probably of Devonian age.

No. 4. *Cant Hill, West end, at top of hill*.—This specimen was taken from the same quarry as no. 3, which it closely resembles, but shows a considerable amount of ochreous matter, which is distributed in small patches and films throughout the rock. Calcite seems, however, to be absent from this specimen, and there is a large proportion of serpentinous matter, so large, indeed, that by burnishing a smoothly cut surface of the rock with an ivory paper-knife, a fairly good polish can be communicated to it.

* I would here acknowledge the courtesy of Mr. Wm. Buller, of Cant, in giving me useful information concerning the quarries in the neighbourhood.

When we examine a section of this rock under the microscope, we find that some of the original glassy basis has to a large extent been converted into serpentine, especially along lines which seem to indicate fluxion-structure. How far this process of alteration has taken place in the glass it is difficult to determine. There may be a little unaltered glass still remaining; but this is a doubtful point. The glassy or once glassy portions of the rock are of a yellowish-brown or coffee-colour, and are full of vesicles which are frequently filled with chalcedony and often give the dark cross common to radiate crystallizations when viewed between crossed nicols. There is, in addition to the serpentine, a large proportion of kaolin present.

Nos. 5 and 6. *Cant Hill, East side, at foot of hill, not in place.*—In sections nos. 5 and 6, cut from specimens collected from débris on the shore, on the east side of the hill, nearly opposite the slate-quarry, we find the same vesicular lava, devitrified and in a more or less crushed condition*, with a very considerable admixture of calcite, serpentine, and some felsitic matter. Quartz often occurs in the vesicles. There seems, then, no doubt that the upper portion of Cant Hill, which has been mapped as "greenstone," is really composed of a basic lava of a once vitreous character, but so altered that its original mineral constitution cannot be inferred with precision. Whether the patch mapped as greenstone on the western side of the estuary, stretching from Oldtown Cove to Tregony, and the exposures on the east of Cant Hill, touching Tregenna and Dinham House, are extensions of this lava of Cant Hill, I am unable to say, as I did not visit those localities; but, judging from their relative positions on the map, it seems by no means an improbable supposition.

No. 7. *Carlion, near St. Minver.*—These specimens were collected in a small quarry on the top of a hill situated close to Cant Hill, a road leading down from this quarry to Cant Farm being at the time mended with some of this freshly broken stone.

It is a compact, greyish-green rock, with dark green or greenish-black blotches, which, when it is roughly broken for road-metal, look at first sight like rain-spots on an absorbent stone. Here and there these spots show glistening cleavage-planes.

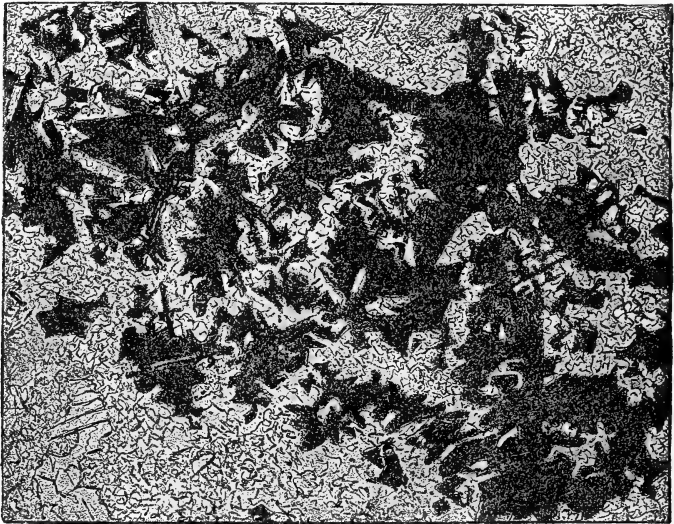
Under the microscope the constituents are seen to be augite, triclinic feldspars (apparently labradorite), ilmenite, a considerable amount of felsitic matter, a little chalcedony, and, in some cases, serpentine. The most striking features of the sections are the crystals of augite. These are seen to be broken up into exceedingly irregular patches, in places somewhat like the pieces of a dissected puzzle, loosely shuffled together or slightly pushed apart (fig. 2, p. 398); this is due to the augite crystals having enveloped small feldspar crystals and feldspathic portions of the rock during the process of crystallization, and not to any corrosive action.

In most cases the enveloped feldspars have been converted into felsitic matter, a fate which many of the larger feldspar crystals have also shared.

* Prof. Bonney is strongly inclined to regard no. 6 as an ash.

That these irregular patches and labyrinths of augite represent individual crystals and not aggregates of crystals, there can be no doubt whatever, since extinction takes place simultaneously and uniformly, both over the connected and the isolated portions of each patch or labyrinth.

Fig. 2.—*Augite-andesite** from Carlion, near St. Minver, Cornwall.



The figure shows one of the remarkably labyrinthine crystals of augite as it appears in a position of maximum extinction between crossed nicols. Part of another crystal of augite, lying in a different azimuth, is represented in the lower left-hand corner of the drawing. The interstitial portions consist of altered feldspars and felsitic matter. Specimen no. 7, $\times 25$. Crossed nicols.

Here, then, somewhat as in the case of micropegmatite, we have a well-marked instance of interruption in the development of individual crystals by the synchronous formation of smaller crystals of another mineral †.

Similar interruption in the development of crystals is, indeed, a very common feature in crystalline eruptive rocks; but it is seldom seen to occur in so striking a manner as in this rock from Carlion. Different grades of such interrupted crystallization are shown in Prof. Judd's recent paper on the "Gabbros, Dolerites, and Basalts of Ter-

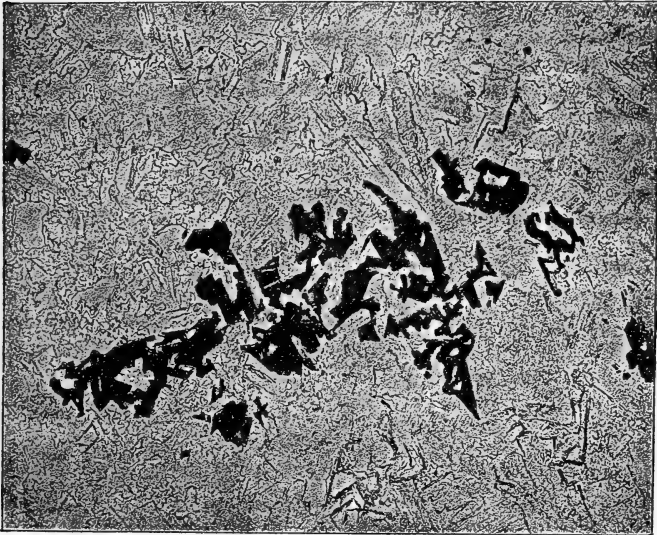
* In using this term, mineral constitution only has been taken into consideration.—F. R., June 28, 1886.

† In this case, however, the mineral causing the interruption consists of small *individual* crystals, thus differing from micro-pegmatitic structure, which is due to interruption of crystallization in *both* of the minerals concerned.

tiary Age in Scotland and Ireland," pl. v. figs. 1, 3, and 5; and Prof. Green has lately shown me some good examples from Rhobell Fawr occurring in rocks, probably of Llandeilo age, and from another spot two miles E.N.E. of Dolgelly, intrusive in Lingula-flags.

Taking certain parallel lines as traces of cleavage-planes, parallel to the vertical axis, we get the maximum extinction in some of the

Fig. 3.—*Augite-andesite from Carlion, near St. Minver, Cornwall.*



The black labyrinthine patch in the middle of the drawing is ilmenite; whether this patch consists of a single crystal or of an aggregate of crystals of ilmenite is uncertain. The remainder of the drawing represents triclinic felspars (more or less altered), felsitic matter, augite, and serpentine.

Specimen no. 7, $\times 25$. Ordinary substage illumination.

augite sections in the Carlion rock at an angle of 39° from this direction. In other sections the angle varies, but usually ranges from 30° to 40° . Tested with a single nicol, the thin sections of this mineral show little or no appreciable trace of pleochroism. These crystals depolarize in vivid colours, and, when seen by ordinary transmitted light, appear of a pale greenish tint. It is also noteworthy that in sections of this rock the ilmenite frequently presents a similar labyrinthine appearance, as shown in fig. 3; but owing to the opacity of this mineral and the irregular outlines which these ilmenite patches present, it is difficult to say whether we are dealing with one crystal or with many.

The rock itself is an augite-andesite* (so far as its mineral con-

* Many petrologists may object to the application of the name andesite to this rock, since it is holocrystalline; but if, in defining an andesite, we admit and require the presence of a ground-mass, we then have two terms for one rock,

stitution is concerned), or what, a few years ago, we should have called a basalt or dolerite; and if a name based upon colour be worth anything, it is also a very good greenstone, and as such it was formerly mapped by the Geological Survey. The other exposures of eruptive rock in its immediate neighbourhood have, however, been coloured alike; but, although we can see at a glance that the rocks of Cant Hill and Carlion are not of precisely the same character, there is a certain rough justice in this generalization, which was absolutely necessary in the early days of the Geological Survey, since both are rocks which apparently possessed a somewhat similar mineral constitution in the first instance. In the case of rocks which present such frequently ambiguous characters as those of Cant Hill, the work of the microscopist would be more sure if controlled by observations made in the field; but Cant Hill to-day is probably much the same as it was when the Survey mapped it, and there seems little more to be learnt until fresh quarries are opened out.

There are, however, probably points concerning the relation of the eruptive rocks to the slates which would well repay further investigation. If the foregoing remarks should throw any faint glimmer of light on the nature of the rocks at Cant Hill and Carlion, I trust that they may be accepted rather as a slight addition which Sir Henry De la Beche would have made to his own "Geological Report on Cornwall," than as an attempt to correct the work of one of our old masters.

EXPLANATION OF PLATE XII.

Fig. 1. Devitrified basic lava, showing fluxion-structure and vesicles. A large proportion of this section consists of a clear, greenish-yellow to brownish-yellow serpentine. The opaque central band is probably an altered spherulitic structure.

Cant Hill, near St. Minver, Cornwall; east end, at top of hill.

Specimen no. 1, $\times 50$. Ordinary transmitted light.

2. Devitrified basic lava, showing portion of the original glass, slightly altered, a fibrous structure being visible in it when seen between crossed nicols. The extremely vesicular character of the glass is shown in this drawing. The greenish granular matter in the upper right-hand corner is probably epidote.

Cant Hill; west end, at top of hill.

Specimen no. 3, $\times 50$. Ordinary transmitted light.

3. Devitrified basic lava, showing porphyritic crystals of felspar, some of which appear corroded, and numerous small vesicles filled with quartz and serpentine.

Cant Hill; east end, at top of hill.

Specimen no. 2, $\times 25$. Ordinary transmitted light.

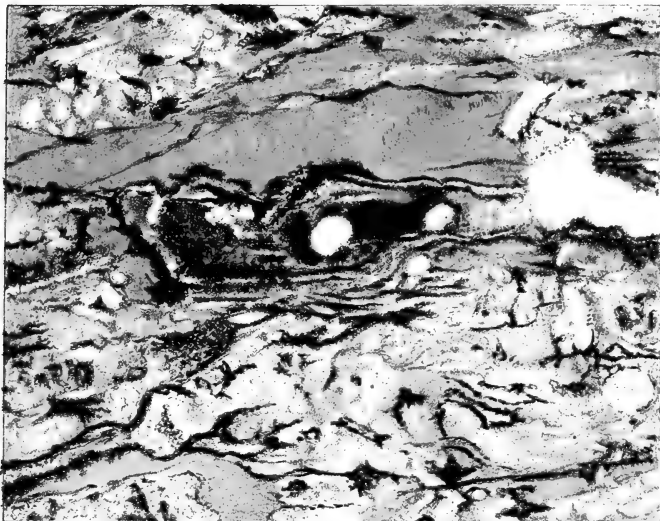
DISCUSSION.

The PRESIDENT remarked on the characteristic treatment by the Author of a difficult subject. He had laid many sides of the question before the Society with the greatest candour.

Mr. TEALL remarked that the specimens from Cant Hill were

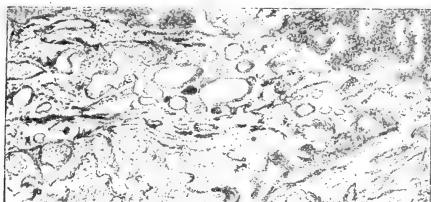
viz. andesite and porphyrite. In its relation to structure the latter term is preferable when a ground-mass exists.—F. R., June 28, 1886.

1.



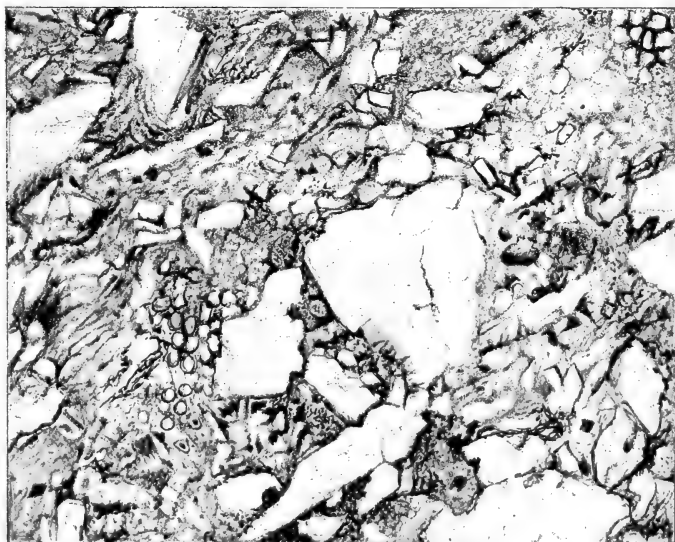
x 50.

2.



x 50.

3.



x 25.

Frank Rutley del.

Mintern Bros Chromo lith.

DEVITRIFIED BASIC LAVAS OF CANT HILL.

schistose. He regarded the schistosity as due, in all probability, to the post-Carboniferous earth-movements, which had undoubtedly produced great structural and mineralogical changes in the pre-granitic rocks of the west of England. He called attention to the fact that many of the so-called "greenstones" of Cornwall and Devon which had been described by Messrs. Allport and Phillips were similar to the proterobases and epidiorites of Gumbel, and to rocks from the Hartz which had been shown by Lossen to be plagioclase-augite rocks in which the augite had been partially or wholly changed to hornblende by contact- or regional (pressure-) metamorphism.

Mr. COLE agreed with the Author that these substances originally contained glassy matter of a basic character, and remarked that whilst the altered glass of the acid lavas had long been recognized, we should have to look for the results of the alteration of the more basic glass in these soft products of yellowish serpentinous matter.

The AUTHOR, in reply, said that there was in this case no direct evidence of alteration from the proximity of granite, nor from the action of shearing, and he showed that in a certain instance there was no displacement of a vein. There had been a disturbance producing a more or less vertical squeeze. He spoke of black as well as of the green alteration-products alluded to by Mr. Cole; the former would result from the separation of magnetite from these basic glasses.

34. *The BAGSHOT BEDS of the LONDON BASIN.* By H. W. MONCKTON, Esq., F.G.S., and R. S. HERRIES, Esq., B.A., F.G.S. (Read June 9, 1886.)

INTRODUCTION.

THE following communication is intended as a supplement to a paper read before the Society by one of the authors in 1883 (*Quart. Journ. Geol. Soc.* vol. xxxix. p. 348), and the two together form an amplification of an article on the same subject by Mr. W. H. Herries (*Geol. Mag.* dec. ii. vol. viii. p. 171).

In our last paper we devoted our attention almost entirely to the Upper and Middle Divisions of the Bagshot series. We now propose to treat more fully of the Lower Division, and to show that the occurrence of pebble-beds is by no means confined to one horizon in the Bagshot series, as would seem to be supposed by some observers.

In the interval much has been written about the geology of the Bagshot district, no less than five papers by the Rev. A. Irving, and one by Mr. Hudleston, having appeared*.

The views lately advanced by Mr. Irving are very much at variance with the hitherto accepted interpretation of the geology of this district, and to a great extent we find ourselves compelled to differ from him. He considers (*Quart. Journ. Geol. Soc.* vol. xli. pp. 506, 507) that the Upper and Middle Bagshot beds, in some places, overlap the Lower Bagshot Beds, and rest directly on the London Clay, which had been thrown into a slight syncline previous to the deposition of the Lower Bagshot strata. He founds his argument partly on the relative thicknesses of the Lower Bagshot beds and the London Clay, as shown by well-sections at various points; partly on the existence of pebble-beds, which he appears always to refer to a particular horizon; and partly on the presence of beds and seams of clay, which he likewise considers an indication that the beds in which they occur belong to a defined

* The following are the papers referred to:—

By the Rev. A. Irving, F.G.S.

1883. "On the Bagshot Strata of the London Basin." *Proc. Geol. Assoc.* vol. viii. p. 143.

1883. "On the Bagshot Sands as a Source of Water Supply." *Geol. Mag.* dec. ii. vol. x. p. 404.

1885. "Water-Supply from the Bagshot and other Strata (2)." *Geol. Mag.* dec. iii. vol. ii. p. 17.

1885. "General Section of the Bagshot Strata from Aldershot to Wokingham." *Quart. Journ. Geol. Soc.* vol. xli. p. 492.

1885. "Excursions to Aldershot and Wokingham." *Proc. Geol. Assoc.* vol. ix. p. 219.

By W. H. Hudleston, Esq., F.R.S., F.G.S.

1886. "On a Recent Section through Walton Common exposing the London Clay, Bagshot Beds, and Plateau Gravel." *Quart. Journ. Geol. Soc.* vol. xlii. p. 147.

position in the series. We shall, we believe, show that the premises from which he draws his conclusions are incorrect.

THE ASCOT-CHERTSEY DISTRICT.

In our previous papers we pointed out that the Middle Bagshot of Bagshot Heath consists of a very well-marked and persistent series of beds, the most important of which is a green sand, as a rule containing casts of marine shells. Above and in this green-sand bed are usually more or less irregular lines of flint pebbles, and still higher we usually find the pebble-bed which marks the base of the Upper Bagshot sands.

In the Ascot Railway-section described in our former papers, these pebble-beds are seen undoubtedly *in situ*. Passing eastwards, the Middle Bagshot Hills are frequently found to be capped with masses of pebbles, and we feel no doubt that these are often the remains of the Middle Bagshot pebble-beds, though in most instances not *in situ*, but more or less re-arranged in post-Bagshot times. This is well shown at the locality three quarters of a mile west of Long Cross, which is referred to by Prof. Prestwich (Quart. Journ. Geol. Soc. vol. iii. p. 389, note). There the green-sand bed is found near the bottom of the hill, and is full of casts of shells; above it is a few feet of yellowish sand, and the hill is capped by a considerable mass of pebbles, obviously not *in situ*; still further east, near Chertsey, is St. Ann's Hill, on the north-eastern side of which are two pits, which, owing to the kindness of the Lord of the Manor, Mr. Bennett, we have been able to examine. The section in the larger pit is published in vol. iv. of the 'Memoirs of the Geological Survey' (p. 332). There is in the upper part of the pit a vast mass of pebbles with green sands and clays mingled together in the most curious manner; and below and down to the bottom of the pit is a considerable thickness of white and yellow sands. Pebbles also occur in whitish sands low down in the pit; but whether *in situ* or not, it is difficult to determine.

The smaller pit is at a lower level than that of the clays and green sands above mentioned; at the east end of it are 20 or 30 feet of fine yellow sands, with thin bands of white clay (which we believe to be the 'pipe-clay' of other observers) and iron-sand, and at the west end yellow sands with irregular patches and non-continuous lines of small pebbles.

The pebbles in the large pit sometimes form a conglomerate, in which we have been fortunate enough to find several casts and impressions of univalve shells, not, however, sufficiently perfect for identification.

The whole of this hill is marked Lower Bagshot on the Geological Survey map, and we admit that the yellow and white sands at the bottom of the large pit and the whole of the small pit belong to that division of the series, but the fossiliferous pebble-beds and the green sands are, we think, clearly of Middle Bagshot age, though we also think it possible that considerable re-arrangement may have taken place in post-Bagshot times.

Whether some of the smaller pebble-beds are not of Lower Bagshot age is a matter of some doubt ; but we are inclined to think that at least one or two of the non-continuous lines and small masses of pebbles in the smaller pit belong to that division of the Bagshot Series.

Upon the Lower Bagshot Sand in this section we make the following remarks:—(a) it is of a white and light yellow colour ; (b) it contains thin seams of white clay (pipe-clay) ; (c) it has masses of pebbles (Middle Bagshot) resting upon and running into the sand, and probably contains one or more non-continuous pebble-beds of Lower Bagshot age.

Now this is of considerable importance, as Mr. Irving sums up the characteristics of the Lower Bagshot Beds in several well-sections thus (Quart. Journ. Geol. Soc. vol. xli. p 496) :—“(ii) There is an absence of all record of pebble-beds in the Lower Bagshot. (iii) The Lower Bagshot Beds are, in all the sections, characterized by the predominance of quartz-sand, coloured green and grey by the presence of organic matter of vegetable origin. (iv) There is an absence of any record of seams of pipe-clay, which are met with frequently in beds of the Middle Division.”

About a mile and a half north-west of St. Ann's Hill, close to the village of Stroude, there is a large sand-pit, of which the section is :—

Section in a Sand-pit near Stroude, about a quarter of a mile north of Virginia-Water Station.

	ft.	in.
1. Greyish sand without much sign of bedding.....	7	0
2. Fine white and yellow sands, false-bedded, with thin lines of pipe-clay	9	0
3. Brown hard sand, of variable thickness, false-bedded..... about	2	6
4. A line of flint pebbles	0	1
5. Yellow ferruginous sand, with thicker and more persistent bands of pipe-clay and signs of wood...	4	6

This is mapped Lower Bagshot in the Survey Map and, we have no doubt, rightly so. The similarity of the sands with pipe-clays to the beds of that division at St. Ann's Hill, and to the other undoubted instances of Lower Bagshots to which we shall refer, and the absence of green sand are our chief reasons for this conclusion ; and we may note that here we have a small Lower Bagshot pebble-bed.

Pebbles are recorded as occurring in the sands near this place in the Survey Memoir (vol. iv. p. 315).

Passing westwards we note the following section :—

Section in Brickfield at Titlark's Farm.

	ft.	in.
1. Green sand, of very dark colour, clayey in places about	6	0
2. Greyish sand and clay, finely laminated, with iron layers and concretions.		
3. And in another pit, on the opposite side of the road, and at a lower level, white sand.		

(Lower Bagshot.)

THE NORTH-WEST OF BAGSHOT HEATH.

Still further westwards we come to an outlier of the Bagshot Beds at Wick Hill, near Bracknell, mapped as Lower Bagshot on the Geological map, but according to Mr. Irving consisting of Upper and Middle Bagshot (Quart. Journ. Geol. Soc. vol. xli. p. 505; Proc. Geol. Assoc. vol. ix. p. 223). This outlier is thus described in the Survey Memoir (vol. iv. p. 316):—"At Wick Hill, north of Bracknell, the *passage-bed* (of the Lower Bagshot Sand) may be seen resting on chocolate-coloured London Clay in a brickyard. Here there may be seen several layers of flint pebbles, six inches or so thick, separated by layers of sand and pipe-clay." Other observers (*e. g.* Professor Rupert Jones, in the discussion on Mr. Irving's paper, Quart. Journ. Geol. Soc. vol. xli. p. 509) have stated that there is an apparent unconformity between the Bagshot Beds and the London Clay at this place.

As therefore this outlier has been the subject of such divergence of opinion, we will record the result of our observations at some length. At the top of Wick Hill, just below the last letter in that name on the new one-inch map, there is a pit in yellowish, rather coarse sand, in and upon which is a considerable mass of pebbles. The surface has been rearranged, as is shown by the presence of angular flints, but some five or six feet down the pebbles appear to be *in situ* in the sand. Further north are two brickfields near the edge of the outlier. That to the east shows about eight feet of numerous contorted layers of yellow sand and pipe-clay, with numerous iron concretions, and a small pebble-bed near the base, resting on dark-coloured London Clay.

That to the west shows fine yellow sands, false-bedded, without pipe-clay, resting on the London Clay; and in the lane close by, at a rather higher level, a pebble-bed occurs in the sands, but this contains some angular flints, and has the appearance of having been re-arranged.

When one of the authors visited these brickfields some years ago, he thought he saw what looked like an unconformity between the London Clay and the Bagshot Beds; but this appearance is not now to be observed, and was probably due to false-bedding. We are, however, unable to agree with the Survey that there is here a passage-bed between the two formations. Nor can we agree with Mr. Irving that this outlier consists of Upper or Middle Bagshot beds. The light and dark yellow sands, bands of pipe-clay, and pebble-beds agree so well with the proved Lower Bagshot beds, already or hereafter to be described, that we have no hesitation in calling them Lower Bagshot, in the absence of any evidence to the contrary; but if there could be any doubt, the entire absence of the green-sand bed which crops out at Cæsar's Camp, Easthampstead, and is no more seen north of that point, is to our minds quite conclusive.

We visited the railway-cutting at Bracknell, described by Mr. Irving (Q. J. G. S. vol. xli. p. 505; Proc. Geol. Assoc. vol. ix. p. 223), but found it much overgrown. The small section exposed

shows about fifteen feet of yellow sands, with lines of clay, and a small pebble-bed near the base, resting on about six feet of yellow, very clayey sand. The surface of the ground at the top of the cutting is covered with rolled pebbles. Mr. Irving considers the pebble-bed in the cutting to be the base of the Upper Bagshot, and the loamy bed below to belong to the Middle Bagshot; but a serious objection to that hypothesis is that he has to place the surface pebble-bed about fifteen feet above the base of the Upper Bagshot, in which series the occurrence of pebbles is most unusual. If, on the other hand, he were to place the upper pebble-bed at the base of the Upper Bagshot, he would have over twenty feet of Middle-Bagshot without green sand, which is also very uncommon. We believe the whole cutting, so far as we have seen it, including the lower pebble-bed, to belong to the Lower Bagshot; and we do not see that any satisfactory evidence has been given to prove that the dark, black and green clay, of which four feet are said to be exposed at the bottom of the cutting (bed "a" of Mr. Irving's section), is not the London Clay, which occurs unmistakably in the cutting on the opposite or west side of the station. If this be so, the section would agree well with that described in the brickfield of Wick Hill, and with the bottom beds of the Lower Bagshot as observed in other places, as, for instance, Aldershot.

The pebble-bed at the top of Wick Hill, which is described as in the Upper Bagshot by Mr. Irving, is about twenty-five feet above the London Clay. It is not easy to say whether it is really a Bagshot pebble-bed *in situ* or not; but as we have shown that at St. Ann's Hill the Lower Bagshot is found with masses of pebbles resting on and running into it, the presence of this mass of pebbles is no sufficient reason for saying that the underlying beds are not Lower Bagshot. The small pebble-bed at a lower level must, if we are right, be Lower Bagshot.

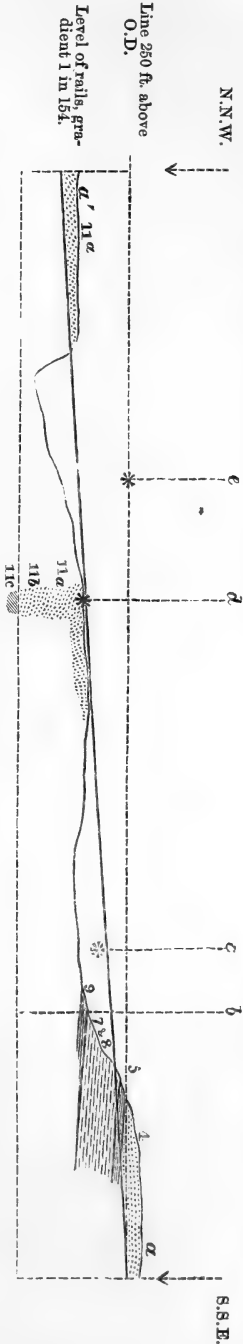
The so-called pebble-beds at the surface, both in the outlier and the adjoining portions of the main mass of the Bagshot sands, are proved by the presence of angular flints to have been re-arranged in post-Bagshot times. This observation applies to the bed described as a pebble-bed by Mr. Irving at Easthampstead Church (Proc. Geol. Assoc. vol. ix. p. 223), for it contains numerous angular flints.

South-west of Bracknell we find the Middle Bagshot green sand cropping out at several points between Caesar's Camp and Wellington-College Station. It is seen on the South-Eastern Railway, a little north of that place, and the section there was described by one of the authors in 1883 (Q. J. G. S. vol. xxxix. p. 351), since which time it has been twice figured by Mr. Irving (Proc. Geol. Assoc. vol. viii. p. 150; and Q. J. G. S. vol. xli. p. 498). We now insert a continuation of our original figure, extending from the station at Wellington College to the Nine-mile Ride, drawn to the same scale as Mr. Irving's; and a comparison of the two will show that, though we agree with him as to the outcrop of the green-sand bed north of the station, we differ from him in our reading of the country north of this point (fig. 1). According to Mr. Irving, a

Bridge at Nine-Mile Ride.

Fig. 1.—Section on the South-Eastern Railway, north of Wellington-College Station. (Scale, horizontal, 6 inches to the mile (i. e. 1 inch = 880 feet); vertical, 1 inch = 88 feet.)

Bridge at the Wellington-Coll. Station.



In the above figure we have used the same numbers for the beds as Mr. Irving (Q. J. G. S. vol. xli. p. 498, fig. 2).

- 4. Tight and dark yellow sand.
 - 5. Dark blue laminated clay, with a line of rolled pebbles.
 - 7 & 8. Green sand with clay, in places much obscured, but seen at the surface in several places.
 - 9. Clays seen in some small pits, and apparently dark-coloured.
 - 11 a. Yellow and yellowish-white sands, sometimes rather clayey.
 - 11 b. Grey earthy sand, } only proved by well-sections at
 - 11 c. Clays, } c and d.
- The surface of the ground is covered with a thin coat of gravel. Mr. Irving makes bed 11 a a continuation of bed 4; 11 b of bed 7 & 8; and 11 c of bed 9.

- a. Pebbles of the Upper Bagshot pebble-bed occur in great quantities at the surface here, but query if *in situ*.
 - a'. Rolled pebbles occur at the surface here, but, being mixed with angular flints, are gravel.
 - b. Line of division between the Middle and Lower Bagshot on the Geol. Survey Map.
 - c. Top of well, described at page 408, is 216½ yards west of this point.
 - d. A new well is 141½ yards west of this point.
 - e. Green sand &c. occurs in the Upwick-Hill Section (fig. 2). 1 mile 220 yards west of this point.
- The stars c, d, and e show the levels of the points referred to.

remarkable anticlinal again brings in the green-sand bed on the north side of the valley, north of the station; whereas we believe that the Lower Middle and Lower Bagshot beds gradually come to the surface, owing partly to a slight southerly dip, and partly to the gradual fall of the ground. Mr. Irving does not contend that the green sand may be seen at the surface north of this valley, but relies upon a well-section on the Devil's Highway (Q. J. G. S. vol. xli. p. 503). Unfortunately, however, we are unable to confirm his description of that section. One of the authors visited the well (the level of which is shown by the star *c* in figure 1) in March 1883; he cannot remember whether the digging of the well was completed or whether the bricking-up had begun; in any case he did not descend, but relied on the statements of the workmen and an inspection of a heap of sand at the side. The following was the entry which he made at the time in his note-book:—

“ *Well at New Lodge.* ”

	feet.
Surface earth	2
Clay	5 or 6
Sand	20 or more.

“ The sand is of a yellowish grey, very hard.—March, 1883.”

The accuracy of this note is borne out by a new well, a little to the north, at the star *d* in figure 1. The authors are of opinion that the sands in these wells are not the Middle Bagshot green sand, but that the clay at the top of the well *c* is the basement-bed of the Middle Bagshot, and the sands and clays below are Lower Bagshot.

We do not therefore admit the alleged anticlinal above referred to, nor that the Upper Bagshots occur on the South-Eastern Railway north of the Wellington-College Station; but we believe that the Middle Bagshot rises at a very low angle to the north, which is borne out by the sections at California and Upwick Hill, shown in fig. 2, the top of which is at the level shown by the star *c* in fig. 1.

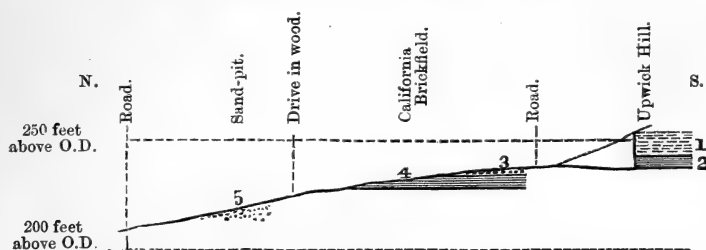
The Geological Surveyors and Mr. Irving assign beds 1 to 4 in fig. 2 to the Middle Bagshot, but we are inclined to place the beds 3 and 4 in the Lower Bagshot, as stated in our last paper (Q. J. G. S. vol. xxxix. p. 350).

Our reasons shortly are the resemblance of bed 2 to the basement-bed of the Middle Bagshot in other sections (Ascot and Goldsworthy for instance), and the difficulty of separating the yellow sands of bed 3 from those of bed 5, which latter we have no doubt are Lower Bagshot. About one third of a mile north-east of this brickfield, and at about the same level, there is a section at the California Rifle-Butts, in yellow sand with a few seams of white clay; it is of the usual Lower Bagshot character, and the sands are precisely like bed 5 at the brickfield.

We thus find the Middle Bagshot green sands and clays cropping out along the side of the hill, and the Lower Bagshot coming to the surface to the north; and we see no reason why a similar

arrangement of beds should not be found where the Middle Bagshots crop out north of Wellington-College Station. Now referring again to fig. 1, it will easily be seen that this must be the case unless we admit Mr. Irving's anticlinal, against the existence of which we

Fig. 2.—Sections at Upwick (or Wick) Hill and in the California Brickfield, near Finchampstead. (Scale, horizontal, 6 inches to the mile; vertical, 1 inch to 88 feet.)



The sections are too shallow for the dip to be seen; but we believe it to be very slight.

The level of the green sand in the section is shown by star *c* in fig. 1.

- | | | |
|-----------------|---|---|
| Middle Bagshot. | { | 1. Clays with green and white sand beds. About 11 feet. |
| | { | 2. Dark blue and reddish clays. 3 feet 6 in. |
| Lower Bagshot. | { | 3. Yellow sand. 2 feet or more. |
| | { | 4. Laminated sandy clay. 10 feet or more. |
| | { | 5. Yellow sand. The pit is 3 feet deep. |

have already given our reasons. It will then follow that the sands in the cutting south of the Nine-Mile Ride must be Lower Bagshot, as mapped by the Survey, and not the upper part of the Middle Bagshot, as Mr. Irving contends. Unless some good reason to the contrary can be found, the beds still further north—that is to say, those of the Wokingham outlier—must also be Lower Bagshot.

On the southern side of this outlier there is a section on the South-Western Railway, near Tangley, where we find about 10 feet of stratified yellow and white sands, rather ferruginous near the bottom, with seams of pipe-clay and signs of wood. On lithological grounds we have no hesitation in assigning this bed and the whole outlier to the Lower Bagshot for reasons similar to those which we have applied to the other localities.

At Hazeley Heath, near Hartley Row, the Middle Bagshot clays are worked for bricks. Above the brick-works, at the highest part of the heath, we saw a bed of rolled pebbles, about 4 inches thick, just below, but quite distinct from, the overlying gravels. Below the pebble-bed are yellow and grey sands, full of green grains, and lower down are grey laminated clays, the whole section of Bagshot beds exposed being not more than 3 feet in thickness. We traced this pebble-bed for a distance of about 250 feet, as far as any openings in the surface were to be seen.

THE ALDERSHOT DISTRICT.

We now pass over to the Aldershot district, and here we admit that at first sight the theory propounded by Mr. Irving appears somewhat plausible.

The hill east of the South Camp, known as Thorn Hill, and on which the Cemetery and the Cambridge Hospital are situated, sends out at its eastern end two spurs. On the N. E. spur a fort has been constructed, and the trenches that have been dug have penetrated through the capping of gravel to the loose yellow sands of Bagshot age. These sands contain small irony concretions, like those described (Geol. Mag. dec. ii. vol. viii. p. 171) as occurring in the Upper Bagshot sands at Tunnel Hill. Here one of us was fortunate enough to find a bivalve shell, which established in our minds beyond doubt that the sands belonged to the Upper Bagshot. In the S.E. spur, just west of the Cemetery, there is a sand-pit showing a good section of brown and yellow sands bedded in rather wavy lines, but not false-bedded. There are no clay bands, but little white patches of clayey sand. These beds show a decided dip rather north of east—that is, in the direction of the main mass of the Upper Bagshot as exposed in the Fox Hills.

East of the Cemetery on the lower hill, just below the fort already mentioned, and just west of the Commissariat Stores, a small opening shows very finely banded white and brown sands, false-bedded, with large ferruginous concretions containing wood in abundance. The sands contain clay patches. Close by there is a mass of pebbles *in situ*, imbedded in a greenish rather clayey sand. This bed is about 3 feet thick, and is seen to overlie the sand bed. This pebble-bed we attribute to the Middle Bagshot, and we think that though the dark green sand beds do not appear, that is only for want of a good section. The ferruginous concretions with wood are very characteristic of the Lower Bagshot Sands, but also occur in the Middle; and it would be difficult, from such a small exposure, to say to which of those two divisions the false-bedded sands underlying the pebbles should be referred. The surface of the ground between the last described section and the base of the N.E. spur is covered with pebbles, and we traced them all round the south side of the hill to the Cambridge Hospital, but no further section of them is seen*, though, judging from the way in which they cover the hill slope, they must belong to a thickish bed. Just below the "C" in Cemetery, in the new one-inch map, there is a small pit, a few feet below the upper limit of the pebbles, showing yellow sands with irony concretions, of Lower Bagshot type.

Crossing over the valley to Redan Hill, we find an exposure behind the Artillery Stores, of about 20 feet of false-bedded white sands, with irony concretions containing wood. These sands are clearly

* The pebbles are exposed in two road-sections near the top of the hill west of the Hospital, and the Middle Bagshot green-sand bed and underlying clays are well shown in a section west of the Farnham Road in the western extension of the same hill.

Lower Bagshot. Ascending the north slope of Redan Hill, the ground is strewn with angular flints, washed down from the thick capping of gravel above; but we did not notice any of the rolled pebbles which occur in such profusion on the side of the hill on the opposite side of the valley, as already described. The inference is that there is no pebble-bed here.

A very fine section is shown in a large sand-pit at the top of this hill east of the railway. In one part of the pit there are 26 feet of white and yellow sands, false-bedded, with thin seams of pipe-clay and iron concretions containing wood. In another part, 10 or 12 feet of higher beds of the same character are exposed; and these are capped by contorted gravels. The beds appear to dip in an easterly direction, but probably in reality rather north of east, as those in Thorn Hill.

The adjoining railway-cutting through the hill, described by Mr. Irving (Q. J. G. S. vol. xli. p. 501), shows similar sands, with seams of pipe-clay occurring both near the top and about halfway down. We found no marine fossils in the concretions, though we made a careful search both in the cutting and in the sand-pit. Wood, however, is abundant.

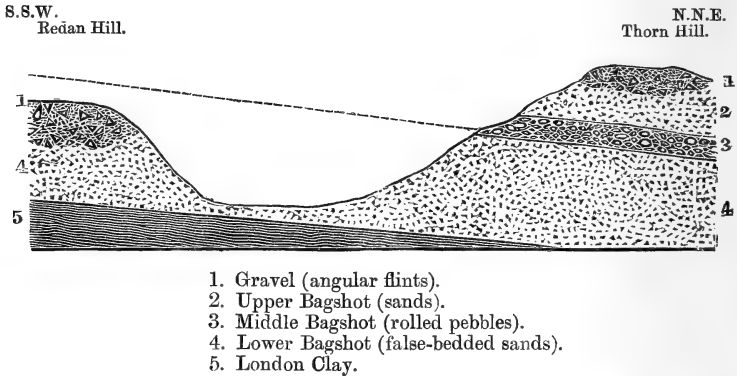
Mr. Irving describes the occurrence of pebbles in a stiff loam in this cutting. We noticed a pebble or two in the sands near its base, but nothing that could be construed into a pebble-bed. Mr. Irving, however, considers the "pebble-bed" here to be the same as that on the south slope of Thorn Hill, and all the yellow sands above it to belong to the Upper Bagshot, and thereupon constructs a diagram (*loc. cit.* p. 502) giving a southerly dip to the beds in Redan Hill, though he admits that the beds appear to dip to the east, but draws the inference that the dip is south of east, from the "occurrence of a line of pebbles at a level some 15 feet lower in a well-section in the cemetery south-east of the cutting." This cemetery (not that on Thorn Hill) occurs, according to the map, to the *North-east* of the cutting, which would tend to support our belief that the true dip is rather north of east. Now if Mr. Irving is correct in considering that Thorn Hill and Redan Hill are similar, he must account for the fact that the sands which he considers Upper, and which overlie his Redan Hill "pebble-bed," contain pipe-clay seams throughout, and especially well up in the sands. This fact is in itself sufficient, in our opinion, to prove that the sands belong to the Lower and not to the Upper series; when, added to this, we have the presence of false-bedding, and the absence of all fossil remains except wood, we think there can be no doubt on the point.

At first sight, it looks as if the two hills, from their position, must be the same; but when we consider the ascertained dip at Thorn Hill and the probable dip at Redan Hill, and their proximity to the sharply tilted beds of the Hog's Back (see the figure p. 376, of vol. iv. of the Survey Memoirs), there is no reason for surprise at the fact that the whole of the beds at Redan Hill underlie the pebble-bed of Thorn Hill and belong to the Lower Bagshot. Thorn Hill, therefore, we believe to be composed of a base of Lower Bagshot,

then Middle Bagshot, and above that Upper Bagshot sands with a capping of gravel; and Redan Hill and the valley between the two we believe to be wholly Lower Bagshot, except for the cap of gravel already alluded to.

The annexed diagram (fig. 3) represents our reading.

Fig. 3.—Section across the Valley of Aldershot Town.
(Not drawn to scale.)



If we have established this, the section in the brickfield on the south side of the town, west of the railway, described by Mr. Irving (*loc. cit.* p. 501) is easily explained. Here the junction of the London Clay and overlying Bagshots is exposed. The Bagshot beds consist of about 14 feet of yellow and brownish-yellow sands, with numerous seams of pipe-clay and many ferruginous concretions, which are especially large and numerous near the base, and they rest on dark-blue London Clay.

Here we find no pebbles or green sand, and the beds are apparently horizontal; and on the whole there does not seem to us any sufficient ground for saying that there is an unconformity.

Mr. Irving contends that the Bagshot beds here belong to the Middle series, and correspond to the loamy beds with pebbles described by him as occurring at the base of the Redan-Hill cutting. We agree that they are on about the horizon of the beds at the base of that cutting, which, owing to the thickness of the overlying sands, must be nearly at the base of the Bagshots; and we therefore consider them to be the lowest beds of the Lower Bagshot*. The loamy bed of Redan Hill is probably, like the beds in the brickfield,

* (*Note*, July 21).—Since this paper has been in the press, we have found that there is a sand-pit in the side of the hill above the brickfield which confirms this view. It is an almost exact repetition of the sand-pit in Redan Hill—20 or 30 feet of false-bedded reddish and white sands with pipe-clay seams and ferruginous partings.

an interstratified series of sand and seams of pipe-clay, such as is frequently found near the base of the Lower Bagshot, as at Wick Hill, Bracknell, and at Tangley cutting already described; and if there is a pebble-bed, it is one of the irregular lines of pebbles, instances of which we have shown to occur in the Lower Bagshot. We therefore contend that there is no evidence here to show any overlap of the Lower Bagshot by the Middle and Upper beds of the series.

THE ASH—WOKING DISTRICT.

The sands at the Ash-Church station on the South-Eastern Railway are undoubtedly Lower Bagshot. The pebbles of the Upper Bagshot pebble-bed are seen in considerable numbers capping the hill to the north-west (not *in situ*), and the green-sand bed crops out along the base of the Fox Hills at a considerably higher level than the station.

Formerly it was well seen in a brickfield which is now disused; it was underlain by clays, which are still shown in another brickfield, rather to the east, at the side of the road close to the figures "240" on the new one-inch map.

That the clay here is the basement-bed of the Middle Bagshot is proved by a small sand-pit at the roadside close to this last-mentioned brickfield; and all possible doubt as to the sands at Ash Church being Lower Bagshot is removed by a roadside cutting in a lane leading from the brickfield to East Wyke Farm, where the Lower Bagshot Sands are seen dipping towards the brickfield and Fox Hills.

Roadside section near East Wyke Farm, Ash.

	ft.	in.
1. Whitish false-bedded sand	1	10
2. Yellow sand and white clay, laminated	1	10
3. Grey and yellow mottled sand, a few concretions	10	0
4. Dark yellow iron-sand	0	10
5. Yellowish sand with several laminae of whitish clay	3	9
6. False-bedded white sands with black grains	5	5

Dip about 3° rather E. of N.

The occurrence of the green sands of the Middle Bagshot at Worplesdon is recorded in the Memoirs of the Geological Survey (vol. iv. p. 333); and in a road-cutting near the church the basement-bed of the Middle Bagshot, consisting of grey laminated clay, may still be seen, and below it are yellow sands, obviously Lower Bagshot. Further east the yellow and white false-bedded sands of Pitch Place and Worplesdon Station (which are at a lower level) are undoubtedly Lower Bagshot.

Between Worplesdon and Pirbright abundance of rolled pebbles occur on the surface. At Ellis Place, $1\frac{1}{2}$ mile south of the Woking convict-prison, the junction of the Middle and Lower Bagshot is again seen in a road-cutting. The Middle Bagshot consists of white clays, with small pipes of green sand; the Lower of fine whitish-yellow sand.

The Goldsworthy-Hill railway-cutting is well known (see Prestwich, Q. J. G. S. vol. iii. p. 382). Close by, a little south of the railway, a road-cutting shows a good section of the junction between the Middle and Lower Bagshots.

	ft.	in.
1. Green sand (Middle Bagshot)	5	0
2. Sandy clay, weathering white, about	4	0
3. Reddish and grey clay, becoming hardened by exposure, containing concretions and stalk-like vegetable impressions, about	12	0
4. Reddish clay, very well-marked bed, forming the base of the Middle Bagshot	0	9
5. Light-yellow sands (Lower Bagshot), more than	18	0

The bedding is apparently conformable throughout; but the line of division between beds 4 and 5 is very distinct.

The new section on the South-Western Railway between Walton and Weybridge stations has been too fully described by Mr. Hudleston (Q. J. G. S. vol. xlii. p. 147) to require more than brief notice; and therefore, while reserving any opinion as to the evidence of unconformity between the Bagshots and the London Clay, we will only observe:—

1st. That the Bagshot beds there exposed are undoubtedly Lower Bagshot, as the Middle Bagshot green sand appears high up in St. George's Hill close at hand (*loc. cit.* p. 170, fig. 8).

2nd. That the Lower Bagshot sands contain:—

(a) Laminæ of clay, and at one point a thick bed of laminated clay (the "Blue Bagshots").

(b) At the base beds of rather coarse sand, remarkably free from ochreous or other investment (*loc. cit.* p. 161).

(c) A few green grains, but nothing which could be termed a bed of green sand.

(d) Numerous woody fragments, at least in one place.

CONCLUDING REMARKS.

We think that the evidence adduced in this and in our two former papers, already referred to (*Geol. Mag.* dec. ii. vol. viii. p. 171, and *Quart. Journ. Geol. Soc.* vol. xxxix. p. 348), warrant us in drawing the following conclusions.

1. *Pebble-beds.*

a. In the Upper Bagshot Sand pebbles are very rare, though there is an instance of their occurrence in the highly fossiliferous bed at Tunnel Hill (*Quart. Journ. Geol. Soc.* vol. xxxix. p. 352).

b. At the base of the Upper Bagshot Sand a continuous pebble-bed is usually, if not always, found.

c. In the Middle Bagshots small pebble-beds occasionally occur.

d. In the Lower Bagshot Beds there are a few small and very irregular lines of pebbles at different horizons. (Instances at Virginia Water and Bracknell are noted.)

e. Besides these pebble-beds, large very irregular masses of pebbles occur occasionally in the Middle and Lower Bagshot Beds at or near the surface, possibly more or less reconstructed.

2. *The Upper Bagshot Sands* contain few, if any, clay bands, are not, as a rule, false-bedded, and have a great abundance of iron concretions, which often either are, or contain, casts of marine shells.

3. *The Middle Bagshot Series* is characterized by green sands and clays. The former frequently contain Bracklesham shells, and they do not lose their green colour by weathering, even when exposed for a considerable length of time, as, for instance, at Goldsworthy Hill.

4. *The Lower Bagshot Beds* are, as a rule, false-bedded. They frequently contain seams of pipe-clay, and sometimes thicker beds of clay occur. There are numerous iron concretions; but, unlike the Upper Bagshot, marine shells are rarely, if ever, found, though wood is common. They never when exposed contain dark green-sand beds, though beds of green sand attributed to this series have been described in well-sections.

With regard to the fossils which are found in the Bagshot beds, Mr. Irving makes the following observations, which we think require explanation. He says (*Quart. Journ. Geol. Soc.* vol. xli. p. 508) "this is borne out by the numerous casts of diminutive forms of a saltwater fauna which are met with in the buff-yellow sands of the Upper Bagshot, at horizons not far above the pebble-bed at the base," and (same page) "The difficulty in the way of the theory suggested in this paper arising from the presence of marine shells, (*e. g.* at Yateley) in the Middle Bagshot beds, may be perhaps removed if we recollect that (1) they occur very locally; (2) they are, as a rule, much broken, worn, and even comminuted; (3) they appear to be confined to the coarser sediments of the Middle Bagshot beds."

In our experience the Upper Bagshot fossils are of the size usual in Barton beds, and not confined to any particular horizon, but the best-preserved specimens are found high up in the series.

The Middle Bagshot fossils are usually present wherever the green-sand bed occurs; they are not, as a rule, broken or comminuted, but entire, the valves of the bivalves being generally united, and any breakage that may be apparent being the result of pressure after deposition.

Now, if geologists, adopting the theory of Mr. Irving, assign much of what has hitherto been recognized as Lower Bagshot to the Upper Division, they will have to deny the truth of many of these conclusions, which, in the face of the evidence which we have brought forward, we do not think they will feel themselves warranted in doing. They will have to account for the absence of green sand where it ought to occur, for the presence of false-bedding and pipe-clay where we should not expect to find them, and for the absence of fossils at horizons at which they may usually be discovered. They have also to account for the peculiar ground-

plan presented by the beds on the overlap theory. It cannot be denied that the Middle Bagshot beds make their appearance at the surface all round the central mass of the Upper Bagshots; and then around this, according to the proposed reading, is an outlying ring of Upper Bagshots, a kind of Saturn's Ring to the central planet, as represented by the Fox Hills, Chobham Ridges, and Easthampstead Plain. This may seem to be putting the case rather too strongly; but we think that whatever it is, Upper, Middle, or Lower, this outer ring mapped by the Survey as Lower and in part claimed by Mr. Irving as Middle and Upper, must all go together, at least along the north and south of the main mass. Such a feature as would thus be presented must be admitted to be most unusual. Then, again, the overlap theory requires the London Clay to have assumed a basin-shape before the deposition of the Bagshot series upon it; and this would require a considerable interval of time, so much perhaps as to give support (were it not for fossil evidence) to the old theory alluded to by Professor Prestwich (*Quart. Journ. Geol. Soc.* vol. iii. p. 380), that the beds in question correspond in age with the Crag of the Eastern Counties.

But the authors, though they think that the evidence, such as it is, goes to show that the Lower Bagshot does not rest conformably on the London Clay, yet consider that there is a general uniformity in the lie of the beds,—that the interval in time between the deposition of the London Clay and the Lower Bagshot was not, by comparison, considerable,—and that the same earth-movements which gave a basin-shape to the London Clay had a precisely similar effect on the overlying Bagshot Series.

Stress has been laid on the fact that no pebble-beds have been recorded in the Lower Bagshots in well-sections; but unless their insignificance has caused them to be overlooked, their absence is but a further proof of the irregularity of their occurrence.

With regard to the relative thickness of the beds at various points, we can only say that measurements obtained from well-sections alone should not be accepted too readily, and we can hardly expect to find that the beds would retain the same thickness throughout an area so large as that under discussion.

We think we have now said enough to fulfil the objects of this paper viz.:—to give additional details of the Lower Bagshot beds of the area of Bagshot Heath, and to defend, we hope successfully, the interpretation of the succession of beds in this district, originally suggested by Professor Prestwich, and adopted and confirmed by the Geological Survey, from the vigorous attack recently made on it.

And, in conclusion, we claim to have proved that the Lower Bagshot is not overlapped by the Upper and Middle portions of the series, and that the Bagshot strata do, as a whole, lie in a synclinal curve.

DISCUSSION.

The PRESIDENT said that a series of new correlations like those suggested by Mr. Irving could hardly be accepted without a re-examination such as that made by the Authors.

Mr. GARDNER said that any one familiar with the lithology could, in most cases, make a distinction between the different members of the Bagshot series; the fauna constitutes a distinction between the Upper and Middle beds, but as regards the Lower beds this fails us.

Mr. HUDLESTON observed that, so far as the Walton-Weybridge section was concerned, it confirmed Mr. Irving's views as to the absence of pebbles in the Lower Bagshots. There might be an overlap on the north and south flanks of the basin, without such a feature elsewhere.

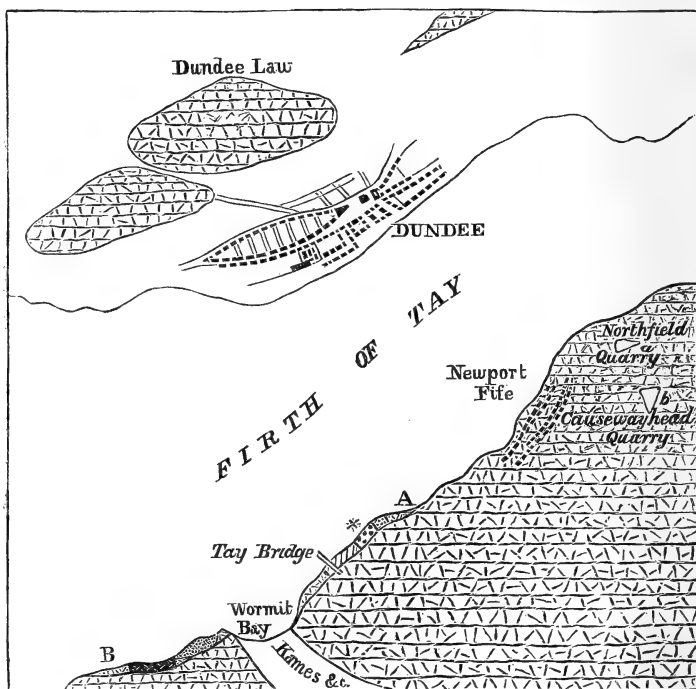
Mr. MONCKTON, in reply, said that the Authors had been much interested in Mr. Irving's theory, and had determined to test it for themselves; the results were unfavourable to his views. In reply to Mr. Hudleston, he stated the existence of a pebble-bed in the Lower Bagshot of St. Ann's Hill, but not continuous. Finally he insisted that numerous sections, described or referred to in the paper, at Bracknell and elsewhere were unfavourable to Mr. Irving's views.

35. VOLCANIC ROCKS of the NORTH-EAST of FIFE. By JAMES DURHAM, Esq., F.G.S. With an APPENDIX, by Prof. J. W. JUDD, F.R.S., Pres. G.S. (Read June 9, 1886.)

[PLATE XIII.]

THOSE who are acquainted with the more salient features of the geology of the great central valley of Scotland are aware that the broad band of Old Red Sandstone which extends from the base of the Grampians about twenty-five miles to the south-east is intersected by belts of volcanic rocks in lines, running from north-east to south-west, nearly coinciding with the strike of the beds. Of these volcanic belts by far the most extensive is that which forms the

Fig. 1.—Sketch Map of the Country round Newport, Fife.



For explanation of symbols, see fig. 2, p. 421.

A-B. Line of section, fig. 2.

a, b. Quarries in andesite rock.

* Dacite-glass in breccia.

southern boundary of the Lower Old Red Sandstone in this part of Scotland, and crosses the country almost uninterruptedly from sea to sea. It comprises some important ranges of hills, of which the Ochil range is the most conspicuous.

The north-east extremity of this great belt of volcanic rocks reaches the North Sea at the south side of the Firth of Tay, and forms, with certain interruptions, the southern shore of the estuary for some 18 or 20 miles; it here varies from five to ten miles in width, and on its south-eastern edge is in contact with the Upper Old Red and Carboniferous rocks. It seems probable that the line of contact is a line of fault.

As may be supposed, the long line of shore in the Firth of Tay furnishes the most convenient section for studying the rocks which compose this igneous belt. Not only are such sections formed by the recent action of the waves of the Firth, but the cliffs of raised sea-beaches in some parts rise one behind the other to the height of two hundred or two hundred and fifty feet, and in many instances these raised cliffs afford sections nearly as good as those presented by the cliffs of the present sea-shore.

In most of the sections these rocks are, at first sight, very discouraging to the student—weathered to one universal dull grey, greatly altered, crushed and faulted, with patches of tuff, breccias, or amygdaloid insensibly passing into what appears solid lava, and solid lava in the same manner passing into apparently sedimentary rocks, no relation or succession can be easily recognized among them. It is therefore not surprising that even able geologists of the last generation simply contented themselves by calling these rocks “trap,” and so passed them by without further notice.

In this apparent chaos, however, observation enables us to recognize the remains of order and arrangement.

In the first place, it is evident that by far the most prevalent rock is altered andesite (porphyrite). So far as I have been able to observe, this rock was erupted from the earliest isolated volcanos of the Lower Old-Red-Sandstone lake, and continued until the great chain of volcanos, which formed the broad belt of volcanic rocks referred to, had reached their maximum elevation. Of the vast mass of lava and other ejecta thrown out from these volcanos only the most insignificant ruins remain to us.

The altered andesite is well exhibited in two quarries, about a mile to the south-east of Newport (fig. 1, *a*, *b*); both of these quarries have been worked for a long time for building-stones and road “metal,” so that they are cut well back into the hill-side. The uppermost of these quarries (Causewayhead) has all the appearance of a volcanic “neck,” while the lower one (Northfield) is formed of flattened columns considerably bent, so that in Causewayhead quarry we have probably the vent of an andesite volcano, while that of Northfield is cut into a great lava-stream. The rocks of both quarries are very similar in general aspect, only that of Causewayhead is more crystalline than the rock of Northfield, as would be expected if the supposition as to their mode of origin be correct.

The next most prevalent rock is a highly altered basalt (melaphyre). The basalt is found almost entirely in the form of dykes and bosses protruding through the andesite, and is consequently more recent than that rock. These basaltic dykes are very numerous

and would seem to indicate extensive eruptions: but the lavas of that period being superimposed upon the andesite have for the most part been removed by denudation, leaving only the channels through which they flowed to the surface as monuments of their activity, though some of the tuffs seem to belong to the melaphyre eruptions. The highly altered basalt dykes do not, as a rule, resist denudation so well as the andesites, and are consequently often represented by trenches in these rocks, the instances in which they form walls being generally the denuded remains of very broad dykes, of which only portions remain, projecting from the hollows. An interesting example of this is to be seen in the picturesque Ghoul's Den, situated about five miles south-west of Newport, which, seen from below, consists of a high mass of rock, on one side of which a burn has cut its way to a great depth, and leaps down the chasm in little cascades; on the other side of the ridge of rock the ground slopes more gently. The central mass of rock is the remains of a broad dyke of altered basalt, the denudation of which has formed on the one side the rugged miniature glen of the stream, and on the other a more gentle hollow, while the whole is surrounded by the prevailing andesite.

Much less frequently met with than the andesites and basalts, though, when present, very conspicuous on account of its light yellow or red colour, is *felstone*; it also is found only in dykes and bosses, and although—as it contrasts very strikingly with the black and dark brown of the andesite and basalt—it is readily recognized when present, I have never found any trace of it among the breccias &c. associated with these rocks.

It is quite clear that the basalt (melaphyre) and the felstone are more recent than the andesite (porphyrite), as these rocks can be seen cutting through the last; but I have been unable to find any direct evidence as to whether the basalt or the felstone came first. So far as I can find or learn, there is no instance in this part of the country of felstone cutting through basalt, or basalt through felstone; but as the succession of the volcanic eruptions among the Palæozoic rocks of other parts of the country shows that the acid rocks succeeded the andesite, and were followed by the basalts, it is perhaps safe, in the absence of evidence to the contrary, to assume a similar succession in this district.

As may be supposed, the aspect of miles of rock exposed in the cliffs of the shore, of dark basalt cutting through darker andesite, with occasional patches of associated tuffs or breccias, is a very monotonous one; this monotony is, however, agreeably relieved by a somewhat interesting section, which extends from below the farmhouse of Scroggieside, about two miles west of Newport, Fife, to the fishing-station of Jock's Hole, about two miles further to the westward.

At the extreme west end of the section is a great mass of felstone extending some two hundred yards along the beach.

To the eastward of the felstone, beds of sandstone, composed of quartz-grains mingled with volcanic ashy material, and in some parts

E.

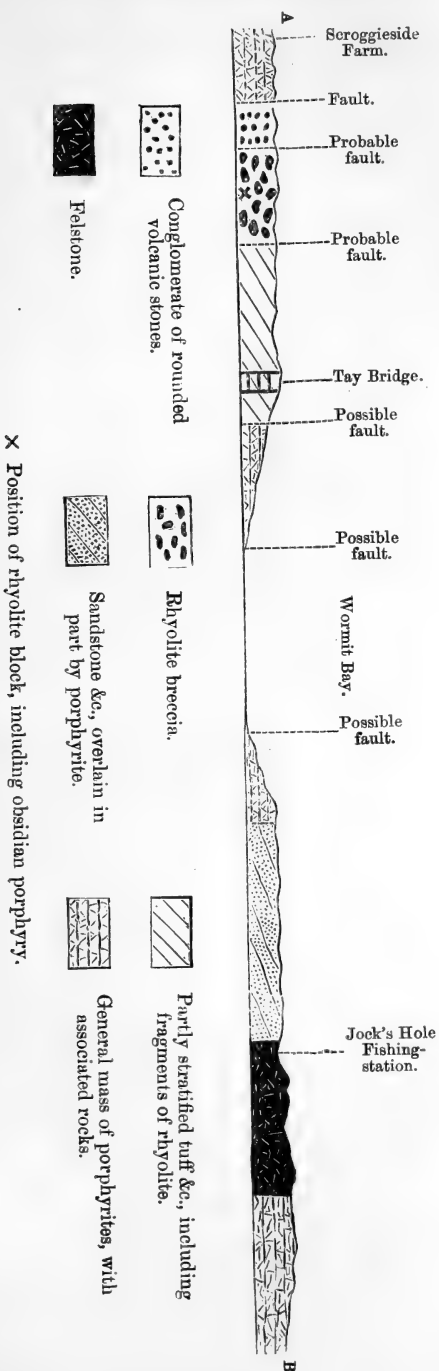


Fig. 2.—Section along the Coast from A to B in Map (Fig. 1).

W.

consisting entirely of volcanic ash, finely stratified, extend along the beach some five or six hundred yards. These sandstones are much altered, and in some instances overlain by altered andesite, into which the sandstones seem to pass insensibly. In proximity to the felstone the sandstones and andesites are greatly altered, both in texture and colour, the dark grey sandstones and nearly black andesite being changed into a rock almost undistinguishable in hand specimens from the yellow sandstone of the Lower Carboniferous rocks. As the distance from the felstone increases, the rocks, both sedimentary and volcanic, gradually assume their natural colours. Further to the eastward the sandstones gradually lose their characteristic appearance, and seem to pass almost imperceptibly into the altered andesites and basalts until they are entirely replaced by these rocks, which continue along the shore until interrupted by a remarkable gap in the otherwise continuous wall of rock which guards the Firth. This gap is on the shore of Wormit Bay, from side to side of which no solid rock whatever is met with. Backward from the shores of the bay, the hills are replaced by a great series of "kames" and gravel-terraces, which extend through the gap some four or five miles to the south, where the opening joins the flat plain of the valley of the Eden, which is on the Upper Old Red Sandstone.

The proximity of these younger beds to the gap in the volcanic rocks suggests as an explanation of it, that the rock underlying the "kames" is probably a continuation of the Upper Old Red of central Fife, let down by faults into its present position. This faulting down of the Upper into the Lower Old Red beds is a familiar phenomenon in the neighbourhood. In Forfarshire and Perthshire, on the other side of the Firth of Tay, several examples occur of isolated patches of the upper series being let down into the lower, while faults along the face of the Braes of Gowrie on the north side of the firth, and on the Fife shore opposite, have thrown the Upper down to a much lower horizon than the volcanic rocks of the Lower Old Red. Indeed it seems probable that all the Upper Old Red Sandstone remaining has been preserved by being faulted down relatively to the Lower.

To the eastward of Wormit Bay, the altered andesites &c. extend along the shore for a short distance, until at a point a little to the west of the Tay Bridge they are interrupted by a fault, which brings down among them a very different class of rocks from any found elsewhere in this district. About half a mile to the eastward, another fault abruptly terminates this exceedingly interesting series of rocks.

The fault which forms the eastward boundary of these rocks is just under the farm-house of Scroggieside. To the westward of this fault the andesites and basalts are replaced by a conglomerate of well-rounded volcanic stones, which are waterworn fragments of highly altered andesite. The matrix of this conglomerate is formed of a consolidated sand of the same rock, so that the general aspect of this part of the section is very dark, but here and there angular

pieces of a bright red rock, closely resembling some rhyolites, are conspicuous among the darker stones; this reddish rock is pronounced by Professor Judd to be a quartz-andesite (dacite). Though some of the fragments of this rock are more rounded than others, still, as compared with the water-worn boulders which form by far the greater part of the conglomerate, they are remarkably angular.

I have not been able to find any trace of the dacite either to the eastward of the fault at Scroggieside, or to the westward of that near the Tay Bridge.

To the west of the conglomerate, with possibly a slight fault between (the nature of the ground making it difficult to determine the point), is a breccia extending about two hundred yards along the shore; it is almost entirely composed of dacite, the included blocks varying in size from minute fragments scarcely visible to the naked eye, up to great masses, some of which must weigh several tons, a large proportion of them being from two to three feet in diameter. All the pieces of dacite, of whatever size, are sharply angular, just as they must have been when freshly broken off the parent rock. The matrix of the breccia consists of minute fragments of very different volcanic rocks; among these the dacite is readily recognizable by its bright colour, contrasting with the pale green of the other constituents. These minute fragments are seen with the aid of a lens to be as sharply angular as the great blocks.

Another notable feature of these dacite blocks is that almost all of them contain hollows or cavities, some of these being very large in proportion to the size of the block.

An examination of these hollows shows that in most of them traces, and in some instances considerable quantities, of a white powder are present. The origin and nature of this white powder is not at first very apparent, as it is clearly not derived from the decay of the dacite, the sides of the cavities being hard and sharp.

Some years ago a full explanation of the phenomenon was afforded by the abnormal action of the tidal currents, probably aided by a storm which laid bare a part of the rock on the plane of the beach, which is usually buried under gravel and fallen fragments of rock from the overhanging cliff. This exposed a very large block of dacite some six or eight feet in diameter. In the block was a large horizontal cavity some five feet across; round the sides of the cavity was seen the usual white powder, but the greater part of it was occupied by a glassy rock, bearing a very close resemblance to the pitchstone-porphyr of the Hebrides, a rock which one is scarcely prepared to find among the ruins of the Lower Old-Red-Sandstone volcanos. However, all the tests that could be applied to it went to show that it was an acid glass, in many ways related to pitchstone-porphyr. To set doubts at rest, specimens of it were sent to Professor Judd, who kindly submitted it to a rigorous examination and pronounced it to be a quartz-andesite- (dacite-) glass.

Close to the block containing the dacite-glass, a very similar mass forms part of the face of the cliff. In it a hollow, opening vertically, contains a very large quantity of the white powder. On removing

the fine dust from the top of the contents of the cavity, the central mass, though pure white, is found to be identical in form with the dacite glass in the neighbouring block, but it crumbles into powder shortly after being lifted out. This proves, if proof were necessary, that the white powder is just the last stage of decay of the glassy rock, and that we must therefore conclude that at one time all the cavities in the dacite containing it were filled with the glass.

About two hundred yards behind the dacite-breccia, a railway-cutting exposes a large section of altered basalt (melaphyre). This section is peculiar as showing the basalt in a much more massive form than is to be seen anywhere else in this part of the country; it seems neither to be a dyke nor a volcanic "neck," but is more like part of a great lava-flow. This view receives valuable support from Professor Judd's microscopical examination of two specimens taken from this section; one of these proves to be a "porphyritic melaphyre" (altered basalt), and the other "either a volcanic breccia or the vesicular portion of a lava-stream which has caught up fragments of other lavas," in either case indicating a subaerial eruption.

On the beach immediately to the west of the dacite-breccias, a mass of rock, similar to that exposed in the railway-cutting, forms part of the cliff. Between this mass of basalt and the fault to the westward of the Tay Bridge, the cliff is formed of a series of well-stratified beds of similar mineral constituents to those of the dacite-breccia. In these beds the large constituents of the breccia are represented by microscopic fragments which, having been deposited in the waters of the Old-Red-Sandstone sea, form sandstones almost entirely composed of comminuted dacite and volcanic ash. Some of these beds would seem to indicate that these volcanic materials had been deposited in comparatively shallow water, as the well-stratified beds frequently pass up into others that have little or no trace of stratification. The dip of these beds is well marked, and is, as might be expected, the usual south-east dip of the Old Red Sandstone on this side of the great anticlinal.

Taking into consideration the presence of altered basalt, both in the railway-cutting immediately to the south of the breccia, and between it and the related stratified beds to the westward, as well as the fact that all the fragments of andesite, of whatever size, are sharply angular, I think we are justified in coming to the conclusion that, between the faults at Scroggieside and Tay Bridge, we have the remains of a basaltic eruption in the immediate proximity, if not actually at the spot itself. This volcano had burst through the quartz-andesite lava of the earlier eruption, and blown fragments of it far and near all over the land and into the neighbouring sea, where some of the larger pieces got mixed up with the shingle of the shore and the finer materials were stratified beneath its waters, the huge masses of the breccia being deposited on the land in close proximity to the crater. Like some of the recent volcanos of the Eifel, little else than pieces of the rock through which it burst seems to have been ejected by it.

We undoubtedly owe the preservation of these interesting rocks to their having been let down by faults among the underlying andesites, they having been thereby protected from the action of denudation, which has so completely removed the younger rocks from the rest of the district.

From the foregoing it will be seen that in this coast-section of about two miles, from Jock's Hole to Scroggieside, we have examples of the lavas of the three great eruptions of the Old-Red-Sandstone volcanos, with specimens of the various materials ejected from some of them, ranging from the great blocks of the breccia to the fine ashy dust of some of the stratified beds; the section, therefore, is of considerable interest, but perhaps the most remarkable feature of it is the ancient volcanic glass lying in the hollows of the dacite lava.

APPENDIX.

By Prof. JOHN W. JUDD, F.R.S., Pres. G.S.

Although the particular section described by Mr. Durham has not been examined by me, I have had considerable opportunities of making myself acquainted with the general characters and relations of the igneous rocks of the district where it is exposed. In the year 1876, I spent some months in examining the volcanic rocks of Angus and Fife, under the guidance of the late Sir Charles Lyell, who had such an intimate acquaintance with the geology of the district; and the general conclusions at which I arrived* with regard to the relations and ages of the different types of igneous rocks in that area correspond very closely with the views which Mr. Durham has enunciated in the foregoing paper.

Among the rocks which Mr. Durham has from time to time sent me for determination, there are several which, from the remarkable state of their preservation and the light which they seem to throw upon some very important petrological problems, appear to me to be worthy of detailed description. I am greatly indebted to the author of the paper, not only for the loan of his own collection of rock-sections, but for the readiness with which he has supplied me with ample materials for further study. Three of the rocks referred to in this paper are particularly interesting in their characters, and may be regarded as noteworthy additions to British petrography.

The remarkably fresh rock of Northfield (see Plate XIII. fig. 1) has a specific gravity of 2.68. It is a very typical pyroxene-andesite, with a large amount of glassy base; through this base, microlites of triclinic felspar are scattered in great profusion, with granules of pyroxene, the whole forming a felt of microlites (*Microlithenfilz*). By the use of high powers, it is seen that the abundant glass between the microlites is filled with globulites, trichites, and belonites.

There are no porphyritic crystals of felspar in this rock, but

* See *Quart. Journ. Geol. Soc.* vol. xxxi. (1875) pp. 141-2.

large crystals of a nearly colourless pyroxene are scattered somewhat sparingly through it. These are certainly, for the most part, monoclinic (augite), though some more decomposed crystals certainly belong to the rhombic pyroxene (enstatite). As a rule, however, the specimens of this rock show only the most incipient stages of alteration, the glass and microlites of the ground-mass exhibiting no sign of change, and many of the porphyritic crystals being as fresh as in a recent lava. Nevertheless, this rock is certainly not of more recent geological age than the Carboniferous, and in all probability it must be referred to the Lower Old Red Sandstone! As the augite preponderates so greatly over the enstatite, we may call it an augite-andesite.

It is an interesting circumstance that the porphyritic crystals of the Northfield rock seldom occur singly, but in groups. In some cases (see Plate XIII. fig. 1) we find aggregates of augite and enstatite crystals with traces of what appears to be decomposed felspar between them.

The rock of Causewayhead (see Plate XIII. fig. 2), as pointed out by Mr. Durham, is of more highly crystalline type than that of Northfield; indeed a glassy base is almost wanting in it, though the felspars are usually very imperfectly individualized; it has a specific gravity of 2.79. The rock is seen, under the microscope, to be an aggregate of large microlites of triclinic felspar and pyroxene, with some grains of magnetite. The felspar, from its extinction-angles, appears to be near to andesine in composition, and some of the larger and better-defined crystals exhibit the zoning so common in the andesitic type of rocks. The felspars contain enclosures of apatite and other minerals.

The pyroxene of this rock sometimes occurs in well-formed prismatic crystals, but there is every gradation from these down to rounded and irregular granules. Although very pale-coloured, the crystals usually exhibit a distinct, though feeble, pleochroism, the tints being those which are characteristic of bronzite or the slightly ferriferous enstatite— α and β brownish yellow, γ pale green. The intensity of this pleochroism, however, appears to vary in different crystals. The great majority of these pyroxene-crystals give the extinction characteristic of a rhombic mineral; but I was unable to obtain sufficiently good basal sections to enable me to determine their interference-figures in convergent polarized light. A very striking feature of these pyroxene-crystals is the series of striations and clefts parallel to the base of the prism, which Rosenbusch has so well pointed out as being characteristic of the rhombic pyroxenes*. Although a small portion of the pyroxene in this rock is probably monoclinic—and the mixture of augite and enstatite is a common feature in rocks of this class—yet the great majority of the crystals are certainly rhombic. The rock may therefore be classed as an “enstatite-andesite.”

The only important accessory ingredient in the rock is biotite. There are no porphyritic crystals of any kind in the rock, but aggre-

* Mikroskopische Physiographie, 2nd ed. (1885), p. 393.

gations of pyroxene and magnetite occur scattered through the mass (see Plate XIII. fig. 4), so as to cause the rock to approach the structure which I have described under the name of "glomeroporphyritic"*. It is worthy of notice that where decomposition has commenced in the rock, the enstatite and magnetite crystals in these aggregations are always the first to exhibit the signs of change.

Although both of these rocks have the general aspect of basalts, yet, as olivine is absent from them, I follow the great majority of continental petrographers in classing them with the pyroxene-andesites. I believe that this course is practically more convenient than that of extending the groups of basalt and dolerite by including in them the larger part of the pyroxene-andesites. As the presence or absence of quartz in a rock is regarded as distinctive of important groups, so, it appears to me, may olivine be taken as an eminently characteristic mineral. Olivine, indeed, may be regarded as even more useful in distinguishing a rock-group than quartz; for it appears to be in almost every instance one of the first minerals to separate from a magma, and is almost always clearly individualized, while the silica of quartz-trachyte or quartz-andesite may remain as tridymite, or in some other finely divided and not easily recognizable condition, and in many rocks the quartz is clearly of secondary origin.

The third rock to which I have to call attention is that constituting the red, porphyritic fragments between Scroggieside Farm and Tay Bridge (see Plate XIII. fig. 7). It has a specific gravity of 2.58. The compact hornstone-like base is seen under the microscope to be much decomposed, in some cases showing much separation of chalcedonic silica, but in places traces of an original flow-structure can be detected, and microlites of felspar abound. The porphyritic crystals exhibit the characteristic lamellar twinning of plagioclase felspars, with the extinction of oligoclase. A few crystals of biotite also occur scattered through the rock. The microscopic examination fully confirms the conclusion arrived at by Mr. Durham, that the remarkable "pitchstone-porphry" is only a local variety of this red porphyritic rock. Very similar mica- and hornblende-dacites are found at Lentrathen and other localities in Forfarshire.

The details given by Mr. Durham prove that the rock in question is in all probability of Lower Old-Red-Sandstone age, and in any case it cannot be younger than Carboniferous. Yet in parts of its mass the glassy structure of the rock is perfectly preserved. I believe that this is at present a unique instance in the case of a rock of such great antiquity.

The "pitchstone-porphry" rock is of a dark grey, almost black colour, and has a resinous lustre, occasionally passing to sub-vitreous. White felspar-crystals are scattered abundantly through the glassy mass. The specific gravity of the rock is very low, the mean of a number of determinations made for me by Mr. A. V. Jennings in the Geological Laboratory of the Normal School of Science being only 2.31. The proportion of silica in the rock was found by him to amount to 67.21 per cent.

* Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 71.

Studied microscopically (see Plate XIII. fig. 8), the rock is found to be one of remarkable interest and beauty. Some portions of the glassy base are seen to be quite as free from alteration as any Tertiary or Recent obsidian. Other portions exhibit every stage of the process of secondary change, whereby it passes into the white decomposition-product to be hereafter described.

The minerals of the first consolidation in the rock consist of numerous large crystals of felspar and a few scattered individuals of biotite.

The porphyritic felspar-crystals, which are sometimes of very considerable size, are usually perfectly fresh and unaltered. They in all cases belong to triclinic species, and usually give extinctions characteristic of oligoclase. Their angles are usually rounded, and they sometimes show evident marks of corrosion by the action on them of the magma in which they are enclosed. Sometimes they are bent and cracked, and in these cases the development of the twin lamellæ has been clearly determined by the strains to which crystals have been subjected. Not unfrequently, crystals are found broken into fragments, and these fragments can be recognized lying disunited in the midst of the glass; in one section I observed a single crystal of felspar which had been broken into no less than *nine* fragments, the fractured edges of which corresponded perfectly, although separated by the glassy mass in which they lay.

The biotite is of a deep brown tint, highly pleochroic, the absorption along the C axis being so strong that the crystals, in certain positions, appear absolutely black and opaque when rotated over the polarizer; in other positions they give various rich shades of brown. The biotite-crystals are often bent and frayed out along the principal cleavage-planes; not unfrequently they show the black margin so common in the biotites and hornblendes of andesites. Traces of alteration are seen in some of these biotite-crystals, the mineral sometimes appearing to pass into the dark blue and strongly pleochroic chloritoid*.

The minerals of the second consolidation consist of imperfectly developed microlites of felspar, many of them exhibiting step-like terminations. In no case have I been able to distinguish twin-lamellæ in these crystals; they are either untwinned or simply twinned on the Carlsbad type. There thus appears to be every ground for regarding these minute crystals of the second period of consolidation as being orthoclase.

The glassy base contains numerous trichites, often forming beautiful stellar groups, with dark-coloured globulites; the disposition of these and the felspar microlites of the second consolidation with respect to the large porphyritic crystals reveals a most

* Chloritoid, the optical characters of which have been so well studied in recent years by Barrois (Bull. Soc. Min. Fr. vol. vii. 1884, pp. 37-43), Von Lasaulx (Sitzungsber. d. niederrhein. Ges. in Bonn, 3 Dec. 1883), and Lacroix (Bull. Soc. Min. Fr. vol. ix. 1886, p. 8), is by no means rare among the Scottish rocks. I find it to occur very abundantly in the interesting rock of Ailsa Craig, for opportunities of studying which I am indebted to Mr. Blackwood of Kilmarnock

striking flow-structure. Not only are these minuter elements of the rock arranged in irregular parallel bands, but they are crowded in front and along the sides of the porphyritic crystals, trailing off behind them.

Still more striking and beautiful is the *perlitic* structure of this remarkable rock. I know of no glass, ancient or modern, which exhibits this structure in greater perfection. In many parts of the mass this perlitic structure is curiously complex, the larger spheres into which the mass breaks up enclosing a number of smaller ones, each exhibiting the concentric arrangement of cracks.

This remarkable rock must be classed as a *porphyritic and perlitic mica-dacite glass*. I may add that while I have met with a number of examples of the stony varieties of dacite in the district described in this paper, this is the first occasion on which I have found it assuming the perfectly vitreous character. It appears that this vitreous variety of the rock occurs in scattered nests in the midst of the ordinary stony form. I have seen, in the lava-streams of Lipari, similar angular masses of glass enclosed in the stony rhyolites, and the appearances in both the ancient and the recent rocks suggest that a brittle glassy rock had been broken up and entangled in a more slowly cooling mass that had assumed a stony character. Subsequently this lava itself appears to have been broken up by a volcanic vent being opened below it, and its fragments thus became enclosed among the ejecta of the later volcano.

There is still another point of great interest in connection with this rock. Portions of it carefully dried at 110° C. and then weighed were found, on ignition, to lose no less than 8·90 per cent. of their weight. When fragments of this glass were heated in a flame urged by a powerful blast, they swelled up in cauliflower-like excrescences, till they attained a bulk at least eight or ten times that of the original fragment. The resulting product was found to be a beautiful white pumice, which floats upon water.

I have recently called attention to the same character as displayed by the curious material known as Marekanite*. I find too that the obsidian of Krakataō, which is a *porphyritic enstatite-dacite glass*, not very dissimilar in chemical composition to the rock we are considering, behaves in just the same manner, when strongly heated, and yields a dirty-white pumice, almost undistinguishable from the natural pumice which was so copiously ejected from that volcano during the great eruption of August 1883.

The rocks of Angus and Fife are especially interesting to geologists from the important light which they throw on the mode of decomposition of some very interesting types of volcanic products.

In the year 1874, I described the great masses of altered lavas which had been ejected from the Old-Red-Sandstone volcanos, under the names of felstone, porphyrite, and claystone †. In the following year I had the opportunity of examining the great andesitic vol-

* Geol. Mag. dec. iii. vol. iii. (1886) p. 243.

† Quart. Journ. Geol. Soc. vol. xxx. (1874) pp. 277-289.

canos of Hungary, and a comparative study, by the aid of the microscope, convinced me that these Scottish rocks of Palæozoic age are only altered forms of andesites, like those of Hungary*. Not only do they agree very closely in ultimate chemical composition, but the structures so characteristic of the andesites—such as the zoned feldspars with large glass inclusions, the hornblendes and micas with blackened edges, and the base formed of a felted mass of micro-lites—are all found exactly repeated in the porphyrites. Further than this we have the groups of the augite-andesites, the enstatite-andesites, the hornblende-andesites, the mica-andesites, and the quartz-andesites of Hungary all exactly represented in Scotland by the augite-porphyrites, the enstatite-porphyrites, the mica-porphyrites, and the quartz-porphyrites respectively.

We are indebted to Dr. A. Geikie, I believe, for first pointing out the close agreement between the altered Scottish rocks and those described by continental petrographers under Gustave Rose's and Naumann's name of "porphyrite." Dr. Geikie proposes to class these rocks as "feldspar-magnetite rocks"†, the two minerals named being the only ones which are now recognizable in the altered products. But by examining a series, including varieties in every stage of alteration, the original identity of these rocks with the modern andesites can be very clearly demonstrated. More than this, we are able to detect every stage of the processes by which the transformation was effected.

In the cases of the Northfield and Causewayhead rocks, as in those of the Cheviot andesites so well described by Mr. Teall‡, there seems to be no valid ground for separating them from the similar rocks of Tertiary age. Studying the rocks in which the first stages of alteration appear, we find that it is the ferro-magnesian silicate which is nearly always the first to yield to the agents of change; and, as a general rule, the porphyritic crystals are altered before the smaller crystals of the ground-mass. The enstatites and augites are especially susceptible to this kind of action, and in rocks showing no other kind of change we find these minerals in a more or less advanced state of decomposition.

The *first* stage in the alteration of the pyroxene-andesites consists in the conversion of the pyroxenes into the green decomposition-products for which Vogelsang proposed the name of "viridite." This "viridite," which at first forms only pseudomorphs after the original crystals (see Plate XIII. fig. 3), afterwards extends into the surrounding glass and eventually fills up all the fissures and cavities of the rock (see Plate XIII. fig. 4). The almost structureless "viridite" breaks up into spherulitic aggregations of various hydrated minerals; but when formed from enstatite these can be shown to be largely composed of serpentine, and when formed from augite to consist mainly of delessite. The alkaline and calcic silicates appear to be

* Quart. Journ. Geol. Soc. vol. xxxii. (1876) p. 295; and 'Volcanoes, what they are and what they teach' (1881) pp. 263-265.

† Trans. Roy. Soc. Edinb. vol. xxix. p. 508.

‡ Geol. Mag. dec. ii. vol. x. (1883) pp. 100-109, 145-153, and 254-263.

decomposed and removed in solution, while the silicates of alumina, magnesia, and iron, taking up water, recrystallize in new combinations.

The *second* stage in the alteration consists in the formation of the black opaque products for which Vogelsang proposed the name of "opacite." That this largely consists of secondary magnetite there cannot be the smallest doubt, but it is often intermingled with ferric oxide and its hydrated products. The way in which the opacite is developed at the expense of the viridite is admirably illustrated in many of the Forfarshire rocks. In the midst of the more or less crystalline green mass, black opaque centres appear with a colourless zone around them (see Plate XIII. fig. 5). As these black nuclei increase in size, the colourless zone around them extends itself outwards, till at last we have the whole mass becoming colourless by the separation of the iron from the viridite and its concentration into the opacite nuclei. What is the nature of the hydrous aluminomagnesian silicate left behind, and which also crystallizes in spherulitic aggregates, we can only conjecture, but it is probably not far removed from pennine and clinocllore in composition.

The *third* stage of change in the alteration of the rock consists in the more complete oxidation and hydration of the opacite, by which the brownish and reddish products, designated as "ferrite" by Vogelsang, are produced.

Concurrently with the later changes which we have been describing, the glassy base of the rock often becomes completely devitrified, the magnetite-grains are all converted into hydrated ferric oxide, and infiltrations of these substances stain the whole substance of the rock and even the feldspars themselves. In this way the rocks acquire the red, brown, and purplish tints which usually characterize the porphyrites.

Last of all, the feldspars may become completely kaolinized, calcite, chalcedony, and other secondary products may be formed in fissures, and thus the whole rock passes into the condition of "claystone," which takes the same place in the intermediate series of rocks as the wackés do in the basic.

Of course this series of changes is liable to some modifications according as the composition of the original rock varies, or the conditions to which it is subjected differ. The transformation appears to take place more rapidly when the rock is full of gas-pores, each of which becomes a laboratory of synthetic mineralogy. But though the several stages of the change may overlap to a certain extent, the order stated is that which would seem to be the one which is almost invariably followed.

In the case of the dacite-glass, we find an instance of a special kind of alteration of a very peculiar kind. Secondary change is seen to commence along the perlitic cracks, and to gradually extend inwards till the whole mass becomes white and opaque. In this white mass the feldspar and biotite crystals remain nearly unaltered. It appears to be isotropic, and may be a hydrated acid glass, just as palagonite is a hydrated basic glass. That it contains the bases of the rock and is not a mass of opal is proved by the fact that the mass

fuses, though with but little intumescence, and forms a colourless glass. In separating along the lines of perlitic cracks and around the microlites of the rock, this secondary product forms globiform particles similar to those described in the case of the pitchstone of Meissen by Vogelsang*. (See Plate XIII. fig. 6.)

The white hydrated glass is so soft that it can be scratched with the thumb-nail. When placed in cold water it rapidly breaks up and falls to powder, the unweathered crystals of felspar separating and remaining intact. Dried at 110° C., the mass loses 12.4 per cent. of its weight, and on ignition 10.1 per cent. more is removed. It thus appears that the white decomposition-product contains no less than 22.5 per cent. of water and other volatile products. The dried specimens of this substance contain nearly the same proportion of silica as the original rock.

The material which seems to come nearest to this in composition and properties is the "alumo-calcite" of Kersten, found at Eibenstein, near Rézbánya, which has a hardness of 1 to 2, a specific gravity of 2.1 to 2.2, and contains 86.6 per cent. of silica with a certain quantity of alumina, lime, and water. Substances of this class probably constitute an intermediate stage between the acid glasses and the opals which so frequently result from their decomposition.

The *felstones*, tuffs, and ashy sandstones referred to by Mr. Durham are usually in such a highly altered condition that in most cases it is not possible to do more than speculate concerning their original constitution and characters.

EXPLANATION OF PLATE XIII.

Fig. 1. Pyroxene-andesite (augite-enstatite-andesite) of Northfield Quarry, near Newport, Fife, N.B., as seen with a magnifying-power of 35 diameters. The base consists of a glass filled with felted microlites of plagioclase felspar (Microlithenfilz). Through this base are scattered crystals and aggregates of crystals. One of these clusters is seen near the centre of the field, and consists of clear, almost colourless augite, the crystals being twinned and having rounded outlines; the unaltered condition of these augite-crystals is in marked contrast with that of the associated enstatite crystals, which are much decomposed, and almost completely converted into *bastite*, enough of the original substance remaining, however, to give the characteristic rhombic extinction and other optical properties of enstatite; between the augite and the enstatite crystals there is visible a third colourless substance, of a granular character, which is probably the result of an alteration of felspar. The whole aggregate greatly resembles a fragment broken off from a deeper-seated crystalline rock, with its edges fused and rounded; and we seem to have an example of the structure to which I have given the name of "glomero-porphyritic." The magnetite and felspar microlites are crowded in the glass immediately around this cluster so as to form a dark zone about it.

Fig. 2. Pyroxene-andesite (enstatite-augite-andesite) from Causewayhead Quarry, near Newport, Fife, N.B., as seen magnified 35 diameters. Enstatite (with a little augite), well crystallized in prisms and in rounded granules, is scattered through a base in which lath-shaped felspars have become less distinctly individualized. At many points

* 'Die Krystalliten,' p. 145, Taf. xv. figs. 4, 5.

the enstatite-crystals form aggregates, and in these the mineral is always found undergoing decomposition into viridite, which in turn gives rise to the formation of secondary magnetite and other iron-oxides.

- Fig. 3. "Viridite" pseudomorph after enstatite, from the rock of Northfield Quarry, as seen magnified 400 diameters. The enstatite has first been converted into *bastite* (see fig. 1), and eventually into a pale green amorphous substance in which only a faint fibrous structure can be detected.
- Fig. 4. "Viridite" produced by the alteration of the ferro-magnesian silicates in the rock of Causewayhead Quarry, filling up accidental cracks in the rock and forming veins in it. The section is represented as seen with a magnifying-power of 250 diameters.
- Fig. 5. Portion of the ground-mass of the Northfield rock in which "viridite" has been extensively developed (as seen magnified 400 diameters). The viridite has been converted into a mass of spherulites, each of which gives a beautiful black cross when viewed between crossed Nicols. In the midst of this patch of green minerals circular spots of colourless substance make their appearance, and as these become distinctly developed and increase in size, centres of "opacite" (secondary magnetite) make their appearance. These white zones in turn assume the characters of spherulites, and in many places the "opacite" is seen passing into ferrite (hydrated ferric oxides).
- Fig. 6. Development of secondary products in globiform aggregations, along the perlitic cracks and around the microlites of the first consolidation, in the dacite glass of Tay Bridge End, Fife. (Compare Vogel-sang, 'Die Krystalliten,' p. 145, Taf. xv. figs. 4 and 5.) In the clear unaltered glass may be seen examples of the star-like aggregations of trichites of this rock. The section is represented as seen magnified 250 diameters.
- Fig. 7. Dacite of Tay Bridge End, Fife, as seen magnified 35 diameters. The rock consists of a *felsitic* base, in which great alteration of the original structure has taken place, the development of the hydrated ferric oxides giving it a reddish-brown colour. Traces of the original flow-structure can, however, be detected. Through this base microlites, probably of orthoclase and belonging to the second consolidation, are scattered in profusion. In addition we find large porphyritic crystals, often rounded and broken, of a plagioclase felspar and a few bent and frayed plates of biotite.
- Fig. 8. Dacite glass (vitreous form of last rock) from Tay Bridge End, Fife, as seen magnified 35 diameters. This glass is, in many places, almost perfectly fresh and unaltered. It contains a number of trichites, some of which are grouped in star-like aggregates (see fig. 6) with small felspar-microlites, the whole exhibiting by their arrangement a marked flow-structure. Most conspicuous, however, is the striking doubly perlitic structure of the rock. In addition to the straight cracks, we find a large series of curved ones, which enclose a second and smaller series. Along these cracks decomposition to a greater or less extent is found set up in different parts of the mass (see fig. 6). None of the large porphyritic crystals of plagioclase felspar or biotite are seen in the part of the section figured.

DISCUSSION.

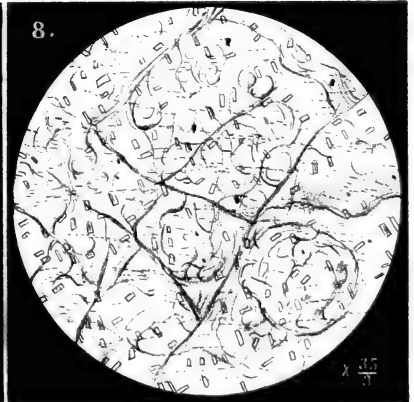
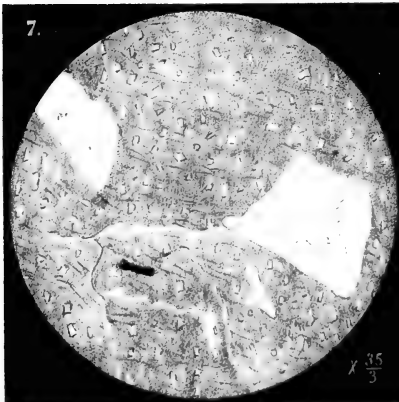
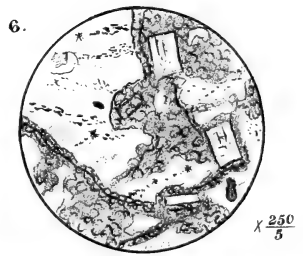
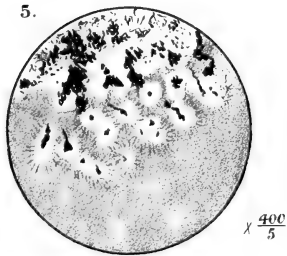
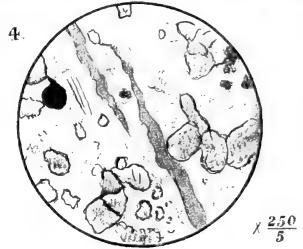
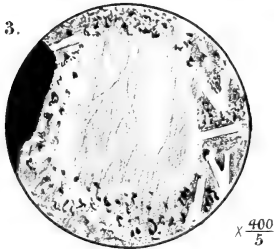
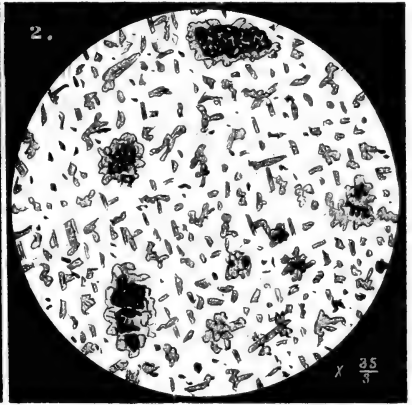
Dr. EVANS, who occupied the Chair during the reading of this paper, observed that Prof. Judd had added greatly to the value of Mr. Durham's paper. The passage from the original form of volcanic products into the various minerals described was of great interest.

Mr. RUTLEY doubted if a distinction were needful between ande-

site and porphyrite. The presence of so much water in a glassy rock, such as that cited by the President, would, if general, account for the development of a vesicular structure in certain obsidians when heated. The instance of perlitic structure was singularly beautiful. He inquired if the larger and smaller perlitic structures shown in the diagram differed in age, his impression being that, in this case, the different series of perlitic cracks represented periods of contraction following so rapidly that the process of fission was approximately continuous.

Mr. TEALL said that the facts described by the President would supply another argument, if such were needed, in support of the view that volcanic rocks of precisely similar composition and structure had been produced at widely separated geological epochs. Referring to the enstatite-andesite he remarked on the rapidly accumulating evidence as to the wide distribution in space and time of the rhombic pyroxenes. He had quite recently detected these minerals in plagioclase-augite rocks from Ratho, Kilsyth, and Arran. As in these cases the rocks were granular in texture and basic in composition, he was inclined to call them enstatite-dolerites rather than enstatite-andesites.

The PRESIDENT, in reply to Mr. Rutley, observed that the smaller perlitic structure is probably slightly posterior to the larger.



Parker & Coward del et lith.

Mirrean Bros. imp.

SCOTTISH ANDESITES AND DACITES.



36. *On the MAXILLA of IGUANODON.*

By J. W. HULKE, Esq., F.R.S., F.G.S. (Read May 12, 1886.)

[PLATE XIV.]

So few cranial remains of *Iguanodon* have been recorded in this country that two fine fragments representing nearly the entire left maxilla have seemed to me deserving of being brought under the notice of the Geological Society*. They derive an additional interest in having been found at Cuckfield, the locality rendered famous by Dr. Mantell's discovery there of a tooth †, the first of that grand series of remains on which, jointly with Dr. Melville, he established the genus. The combined lengths of the two pieces amount to 29 centim., but a small intermediate fragment is missing, and if we estimate this at 1 centim., the length of the entire maxilla will have been not under 30 centim. The maximum vertical measurement in the present state of the jaw is 6·2 centim. These proportions show the form of jaw to be relatively longer and more slender than that of *Hypsilophodon*, from which it also differs in the bluntly rounded, not tapering, shape of its posterior extremity.

The external surface of the jaw slopes outwards as it ascends towards the upper border, and in the articulated skull would overhang the outer alveolar margin. It is perforated by a series of conspicuous vascular foramina. The inner surface of the bone is nearly plane in its posterior, and gently concave in its anterior half. I do not find any indication of palatal expansions. The upper border, the stoutest part of the bone, exhibits a deep sunken groove, which begins in a shallow pit (prelacrymal fossa) opening on the outer surface of the maxilla at 4·5 centim. from its posterior extremity. This groove contracts at a short distance from the external opening, and then, dilating vertically, it passes forward along the bone, and becoming much wider and shallower in the anterior half seems to have led here into the nasal passages. I found indications of this canal in the maxilla of *I. Prestwichii*. Anteriorly the upper border becomes compressed and thinned, and there is evidence that, as in *Hypsilophodon*, the thinned bifid end was overlapped by the body of the premaxilla, an outer ascending or maxillary process of which was received in the wide shallow anterior part of the groove just mentioned. Posteriorly the upper border was overlapped by the outer border of the nasal, and behind this by the lacrymal bone, which contributed with the maxilla to form the prelacrymal opening.

The outer lip of the dentary border is created by the openings of 19 alveoli; and assuming that the missing piece contained 3, the number of teeth in the working line would be 22, a number agreeing fairly with that in *I. bernissartensis* ‡. The teeth exhibit the

* I offer my best thanks to Dr. Willett for most courteously affording me an opportunity of studying these fossils and bringing them under your notice.

† About the year 1820.

‡ Dollo, Quatrième note, in Bulletin du Mus. d'Hist. Nat. de Belgique, t. ii. (1883).

form, sculpture, and wear so characteristic of *Iguanodon*, and they illustrate the successive phases of its dentition, from the germ crown which has not yet descended to the level of the dentary border, through the fully protruded but unworn crown, to the almost final stage where the crown is nearly worn away and the root is being extruded from the alveolus.

From the relatively slender and graceful form of this maxilla, I am disposed to refer it to *I. Mantelli*, rather than to its more massive contemporary *I. bernissartensis*.

EXPLANATION OF PLATE XIV.

Fig. 1. Inner, and Fig. 2. Outer view of a left maxilla of *Iguanodon* from Cuckfield. (About nine tenths of the natural size.)

DISCUSSION.

Prof. FLOWER was glad to be able to announce that Mr. Willett contemplated presenting the specimen to the British Museum. Owing to the unworn character of some of the teeth and the peculiar form of wearing of others, it forms a very instructive example of the genus.

Prof. SEELEY said that, owing to the fragmentary character of specimens, English fossil reptiles had been very carefully studied in detail, and to this study Mr. Hulke had contributed many valuable additions. He asked what were the differences in proportion between this jaw and the typical Brussels skeleton. He remarked on the characters presented by the palate.

Mr. TOPLEY said the quarry at Cuckfield was not only that from which *Iguanodon* was first obtained by Mantell, but that from which almost all Mantell's Wealden specimens, recorded as from Tilgate Forest, were collected. Many fossils were obtained from the same quarry by William Smith.

The AUTHOR said he had nothing to add to what he had already stated. Mantell's species appeared to be slighter and more delicate than *I. bernissartensis*. The palate was very imperfectly known.

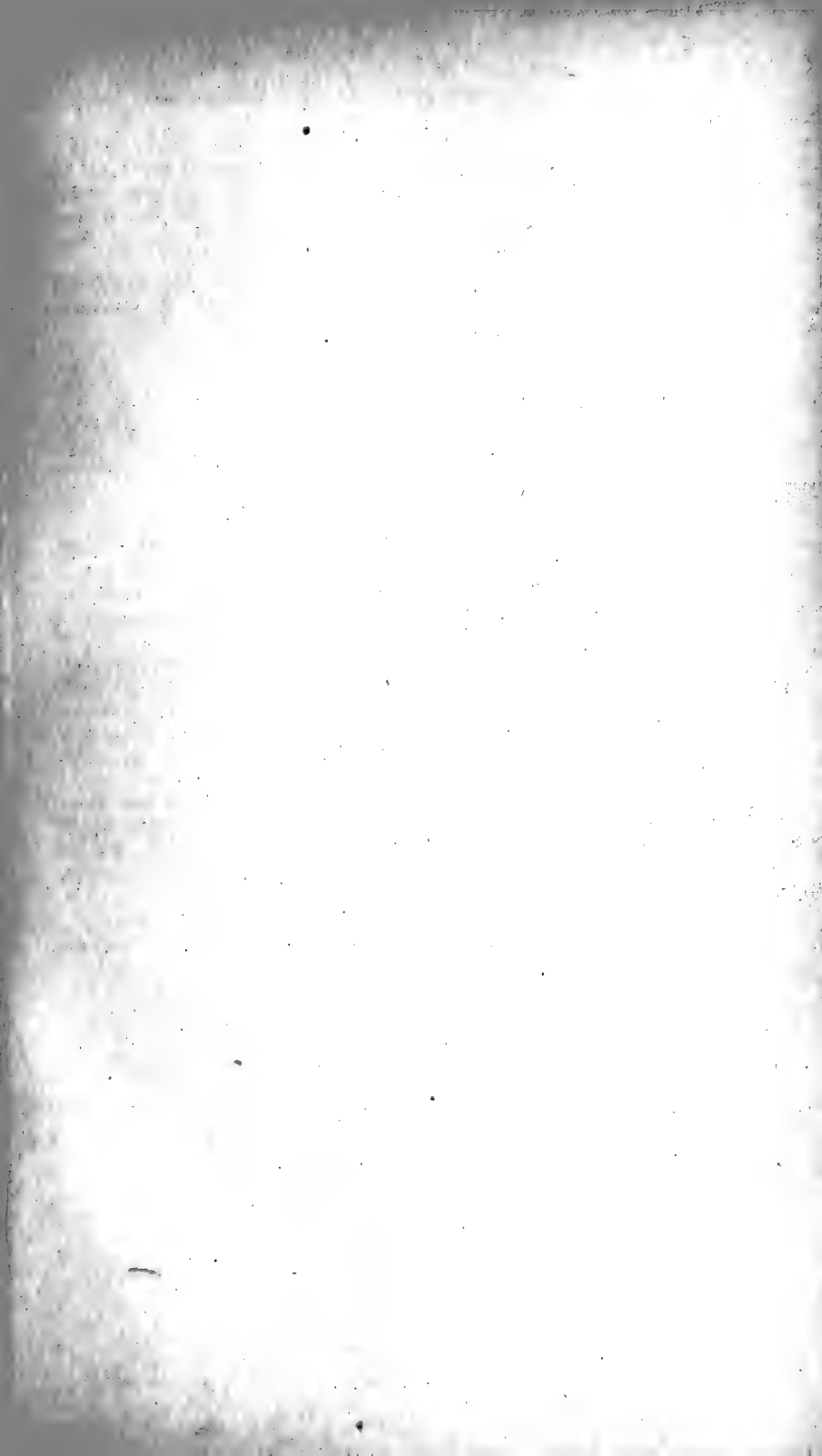




Fig. 1. Inner view.



Fig. 2. Outer view.



MAXILLA OF IGUANODON



37. *The PLEISTOCENE SUCCESSION in the TRENT BASIN.* By R. M. DEELEY, Esq., F.G.S. (Read May 12, 1886.)

INTRODUCTION.

THOUGH the glacial deposits of some portions of the Trent basin have received a considerable degree of attention, no really systematic attempt has yet been made to ascertain their succession, or even to trace the horizontal extension of the more important members of the series. Mr. D. Mackintosh* has certainly stated his opinion concerning the westerly extension of the Great Chalky Boulder-clay, and Mr. Searles V. Wood, Junior †, has also dealt more or less theoretically with the whole subject; but before anything like certainty on these points can be arrived at, the succession over the whole area must be ascertained, and the horizontal extension of each member of the series traced.

Sections have also been described by the Rev. Dr. Crosskey ‡, Mr. W. J. Harrison §, Mr. James Shipman ||, Mr. Molyneux ¶, the officers of the Geological Survey, &c. &c. Many of these exposures, however, are now obscured by talus or overgrown with vegetation, while others I have not been able to visit. Indeed the following paper must be regarded as an endeavour to ascertain the succession obtaining in the Pleistocene deposits of the Trent basin, as shown by sections which I have myself examined, rather than as a detailed account of their distribution.

For assistance in much of the field-work, especially that portion relating to Nottinghamshire, I am indebted to Mr. J. Shipman. My thanks are also due to Mr. A. J. Jukes-Browne, for his advice, and to Mr. J. J. Harris Teall, for the use of his notes.

The observations recorded in this paper were commenced as far back as 1879, in company with Mr. Shipman. At first it was not contemplated to do more than trace out the relations of the drift and alluvial deposits of the country around Nottingham and Derby; but as the work progressed it became clear that in order to do justice to the subject, even as regards this limited area, it was necessary to extend our researches much further afield. This was accordingly done; but, unfortunately, the pressure of Mr. Shipman's engagements prevented him from pursuing the subject with me to the end, and in 1884 he left me to continue the work alone; eventually I decided to take in as much as possible of the great natural geographical division included within the watershed of the river Trent.

* Quart. Journ. Geol. Soc. 1879, 1880.

† *Op. cit.* 1880.

‡ Proceedings of the Birmingham Philosophical Society, vol. iii. pt. 2.

§ Geology of the Counties of England and Wales.

|| Geology of the Parish of Lenton.

¶ Burton-on-Trent; its History, its Waters, and its Breweries.

The importance of ascertaining the succession in this area will be evident when its central position is considered, for, this once accomplished, we should be within measurable distance of correlating the Pleistocene deposits on the west side of the Pennine Hills with those to the east of the same range.

As will be seen from the classification I have adopted and the tracing of some of the deposits into adjoining areas, a basis at least for a tolerably correct correlation of the Pleistocene deposits of England is furnished; but I have thought it wise to leave detailed work in this direction alone for the present.

I. GENERAL DESCRIPTION AND CLASSIFICATION.

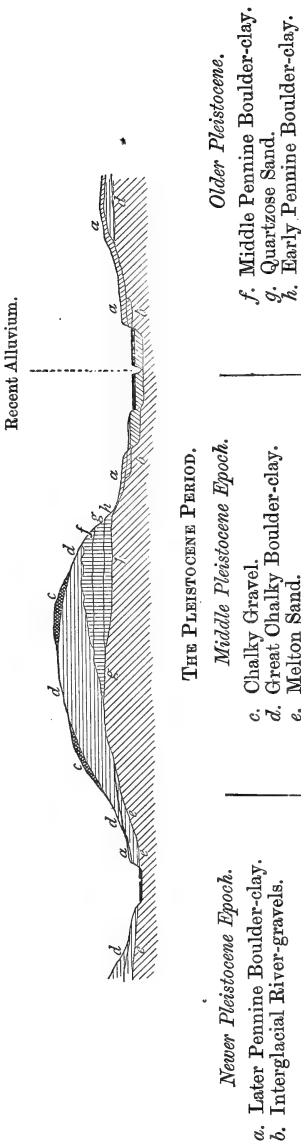
The Pleistocene deposits of the Trent basin are chiefly remarkable for the great development which the glacial beds obtain; they consist of Boulder-clays, gravels, and sands, of various kinds and ages. The distribution of the Boulder-clay varies very much both as regards area and thickness, for in some localities it occurs in great masses occupying small areas, and in others it covers considerable districts with a tolerably uniform veneer; its greatest development is on the plains to the south and east of the Pennine axis.

In the Trent basin the oldest Pleistocene deposits are distinguishable from those of later age by their freedom from Cretaceous rock-débris. Professor Judd, in his "Geology of Rutland and East Leicestershire," recognizes the existence of sands and gravels beneath the Boulder-clay. These sands and gravels he describes as containing local rock-débris, "in this respect offering a very marked contrast with all the gravels of Post-glacial age, which usually contain abundance of chalk flints and rocks foreign to the district." Not only are there, as Professor Judd points out, gravels and sands free from chalk and flint, but there are throughout the Trent basin great thicknesses of Boulder-clay also free from Cretaceous rock-débris, but containing an abundance of Pennine erratics. This feature obtains throughout the whole area, and whenever members of the two series are seen in an undisturbed condition in the same section they invariably occupy the same relative positions; and so great is the lithological difference between the two series, and so largely are they developed, that I have ventured to regard the formation of these early Pennine deposits as marking a distinct epoch in the Pleistocene period, the great physical changes which took place at its close introducing an entirely new series of rocks into the Pleistocene deposits of the Midland Counties, and marking the commencement of a newer epoch.

Another break has been shown by Mr. A. J. Jukes-Browne* to occur at a much later period, between the Chalky Boulder-clay and the Purple Boulder-clay; and though in the Trent basin this was rather a change in the physical conditions of the area than a break indicating lapse of time, there are good reasons for adopting it as another important line of division.

* Quart. Journ. Geol. Soc. 1885.

Fig. 2.—Diagram showing the Succession of the Pleistocene Deposits of the Trent Basin.



According to this classification the Pleistocene deposits fall into three epochs, viz. Older Pleistocene Epoch, Middle Pleistocene Epoch, and Newer Pleistocene Epoch; each of these epochs is susceptible of still further division into stages, each stage indicating very considerable changes in the climate and geography of the British Isles. Fig. 2 is a diagrammatic representation of their succession and general mode of occurrence.

The Boulder-clays of the lower series, or Older Pleistocene epoch, are tough, bluish or reddish clays, chiefly made up of the subjacent rocks or those immediately to the north or west; they contain fragments of all the Pennine rocks. Oolitic and Cretaceous débris only occur in them in the extreme east of England, where the Boulder-clay approaches the outcrop of these rocks. The boulders are, in fact, such as would be brought down by glaciers descending the valleys of the Derwent, Wye, and other northerly and westerly tributaries of the Trent, debouching into and crossing the valley of the latter river.

The clays of the Middle and Newer Pleistocene epochs, among which is included the Great Chalky Boulder-clay, are charged, unlike the earlier series, with large quantities of flint and chalk. In these deposits boulders from the Pennine chain do not form, except in the west, a large proportion of the harder rocks.

The beds associated with the Boulder-clays consist of wide-spread deposits of sand or gravel formed during times of submergence, or of fluviatile gravels occupying terraces bordering the

main watercourses. Like the Boulder-clays, the gravels and sands are of two varieties, each variety possessing distinct lithological characteristics.

Each of the physical changes which caused the Pleistocene deposits to vary over wide areas, from Boulder-clays to gravels, sands, or brick-earths, will be considered as marking a definite stage, the commencement or close of which was not perhaps always exactly coincident over the whole district. No hard-and-fast line really separates the various stages from each other, for the Pleistocene deposits I have had to deal with seem to indicate an almost continuous series of changes from early glacial times down to the present day, the exception being an apparent break at the close of the Older Pleistocene epoch. The development of each deposit also varies largely in different localities.

Few branches of dynamical geology have, of late years, given rise to more divergent views than the question of the origin of Boulder-clays. It is not my intention at present to enter fully into the subject, but a short statement of the opinions formed by their study in the field will help to render my meaning clearer when I come to deal with them in detail.

I do not incline to either an entirely subaqueous or an altogether subglacial hypothesis.

The Boulder-clays may be divided into four distinct types:—

1st. Aqueous Boulder-clay formed near the shore or the terminal front of a glacier where it entered water tolerably free from currents.

2nd. *Moraine profonde* formed beneath a thick ice-sheet by the breaking up of the preglacial rocks over which it moved.

3rd. *Moraine profonde* formed beneath an ice-sheet by the ploughing up and confusing of aqueous Boulder-clays, sands, &c.

4th. Deposits collected at the terminal fronts of glaciers not entering the sea.

Any particular section of Boulder-clay may contain one or more of the above typical forms, or any intermediate variety, for they graduate by insensible stages one into the other.

The aqueous Boulder-clay is generally a fine, stiff, sandy, homogeneous deposit, of various colours, charged with striated, grooved, and polished erratic boulders, many of which have travelled great distances. It often rests upon or underlies beds of sand, with which it is clearly interstratified. Where sand-beds, which frequently show no signs of disturbance, and aqueous Boulder-clays inosculate, the sands frequently lose their false-bedded character, showing that the Boulder-clays were deposited in still water; everything points to their having been formed by the sediment which the subglacial streams brought down and deposited in comparatively still water. The absence of stratification is due to the constancy of the supply of sediment and to there being no strong currents.

The included morainic masses of clay which it sometimes contains are derived from rocks which the ice was denuding at the time, while the striated boulders were released from the thawing under surface of the ice.

The second class of Boulder-clays has been so ably described by Professor J. Geikie, in his 'Great Ice Age,' that there is little to add to his description. It generally consists of small broken fragments of rock confusedly commingled and often presenting a banded or streaky appearance which, from a distance, much resembles stratification. Where it rests upon Pleistocene sands, or even older rocks, these rocks are forcibly contorted or puckered, the puckers running, roughly, transversely to the flow of the ice which formed them. The proportion of unstriated and angular boulders is also much greater than in the aqueous Boulder-clay.

The third variety is frequently a very puzzling deposit, especially when it has been formed by the destruction of Boulder-clay which contained beds of sand or brick-earth; for it then contains pockets of unstratified sand mixed in every conceivable state of confusion with fine clay and broken-up rock.

Very few deposits of the fourth class occur in the lower country, but they are to be seen in the higher valleys of the Pennine Hills.

The following is the classification of the Pleistocene deposits adopted in this paper:—

Newer Pleistocene Epoch.

Later Pennine Boulder-clay.
Interglacial River-gravel.

Middle Pleistocene Epoch.

Chalky Gravel.
Great Chalky Boulder-clay.
Melton Sand.

Older Pleistocene Epoch.

Middle Pennine Boulder-clay.
Quartzose Sand.
Early Pennine Boulder-clay.

II. OLDER PLEISTOCENE EPOCH.

1. *Early Pennine Boulder-clay.*
2. *Quartzose Sand.*
3. *Middle Pennine Boulder-clay.*

The Older Pleistocene series consists of two distinct Boulder-clays separated from each other by false-bedded gravel, sand, or brick-earth. As nearly all the rock-fragments occurring in these deposits are derived from the Derbyshire hills, or from rocks in their immediate neighbourhood, I have called the glacial clays Early Pennine Boulder-clay and Middle Pennine Boulder-clay, to denote their Pennine origin. They are separated from each other by the Quartzose Sand. This sand passes down in some cases into a brick-earth with seams of strong clay, which, in its turn, graduates into Early Pennine Boulder-clay. The wide area over which the

Quartzose Sand is distributed, the elevated districts which it covers, and the persistency with which the current-bedding retains its direction, all point to a period of submergence during which ice-action had partially, if not wholly, ceased.

The lithological similarities presented by these two Boulder-clays render it almost impossible to distinguish the one from the other, except where they are associated with the intermediate arenaceous deposits. Of course the general correctness of the classification will not be affected by the occasional uncertainty as to whether a particular deposit of Boulder-clay is older or newer than the sand.

An idea often finds expression that the presence of any particular rock in a given section is entirely due to chance, and that the whole Pleistocene system is really a confused assemblage of clays, sands, or gravels, charged with rock-débris, brought indiscriminately from all directions. This idea probably arises from the supposition that the erratics were carried by coast-ice and icebergs, which, drifting about under the action of varying currents, carried their burdens to great distances, and scattered them upon the sea-bottom, or thrust them upon the coast-lines. Now in the Pleistocene deposits of the Trent basin such jumbling never occurs without good and evident reasons. In fact the lithological character of each deposit, and the disturbances to which it has been subjected, are each of the utmost importance in giving us a clue to its age, and point to the action of an agency much less fitful than ocean-currents. I do not deny that icebergs and coast-ice have transported boulders to great distances, but regard glacier-ice as the chief agent in determining the distribution and lithological character of Boulder-clays.

In addition to the glaciers which spread over the Trent basin from the Pennine axis, there is every probability that a united Scotch and Cumbrian ice-stream, after passing over Lancashire and Cheshire, entered the westerly portion of the area. The proofs that this occurred in Newer Pleistocene times seem complete, but, owing to the scarcity of Older Pleistocene Boulder-clays in Staffordshire, the evidence is less conclusive for the epoch we are now dealing with than could be wished.

1. *Early Pennine Boulder-clay.*

The Early Pennine Boulder-clay does not appear to have been so largely developed as some of the later beds, an inference supported by the frequent, but by no means general, absence of pebbles of Pennine rock from the sand of the next stage.

South of Leicester, at Oadby, a brick-yard near the racecourse shows reddish morainic Boulder-clay with quartz pebbles and numerous Coal-measure erratics passing up into brick-earth and sand, the former containing bands of strong clay and occasional masses of morainic Boulder-clay.

In the valley of the Wreak, between Syston and Melton Mowbray, the Early Pennine Boulder-clay seems well developed. The only good section occurs at Thrussington.

To do justice to the Older Pleistocene deposits of this valley, it

would be necessary to carefully map the whole area. A rough survey showed that the Early Pennine Boulder-clay probably extends some distance along the south side of the valley between Rearsby and Frisby. No sections are to be seen, but its presence was inferred from the results of some shallow borings.

On the north side of the Wreak, though the deposit is better exposed, its relationship to the later sands and clays is not so easily traced, owing partly to the presence of numerous lateral valleys, and partly to subsequent disturbances.

At Thrussington, in Woldgale Lane, a clay-pit shows a deep section of Boulder-clay capped by what appears to be Quartzose Sand about 9 feet thick. The sand, which is here reddish, is probably much thicker than the section showed. In this pit is exposed at least 30 feet of fine, tough, silty Boulder-clay, with included masses, streaks, or irregular beds of unstratified moraine. These morainic masses have been forcibly intruded or even dropped into the surrounding clay. Though the main mass of the deposit is a tough silty clay, it is thickly studded with very small fragments of rock and occasional boulders. The boulders are well striated, especially the Lias limestone. Keuper marl, green marl, quartz pebbles, and a few Pennine rocks also occur. The quartz and quartzites are most plentiful in the intruded morainic portions. Oolitic and Cretaceous rocks are quite absent.

The clay extends at least as far as Hoby, and maintains a considerable thickness throughout the whole distance. Its junction with the underlying rock is nowhere exposed, but at Thrussington it is said to become more stony and sandy towards the bottom.

Many sections which will be referred to under the Middle Pennine Boulder-clay stage perhaps really belong to the present one, but owing to the lithological similarity of the deposits of the two stages, and the absence of the Quartzose Sand from the sections, their absolute ages cannot be determined with any degree of certainty. My main reason for deferring their consideration to a later stage is due to the much more positive evidence we have of intense glacial conditions towards the close of the Older Pleistocene Epoch.

2. *Quartzose Sand.*

Passing beneath Middle or Newer Pleistocene deposits, capping the hills at considerable elevations, or interbedded with Older Pleistocene Boulder-clays, there are deposits of fine, light yellowish or reddish false-bedded sand or gravel.

That the submergence which these deposits indicate was very considerable in this part of Britain is proved by the occurrence of Quartzose Sand at Blackwall, near Kirk Ireton; on the Long Hills north-north-west of Nottingham; and on the hill-top east-north-east of Gelston, 6 miles north of Grantham.

At Blackwall, one mile south-west of Kirk Ireton, in Derbyshire, there is a very fine section of this sand. It is about 25 feet thick, and consists of coarse sand or grit derived apparently from the breaking up of the Yoredale Sandstone which forms the ridge upon which it

rests. The sand is very pebbly, the pebbles varying in size from that of a pea to as much as six or eight inches long. They consist of quartzites, quartz, brown sandstone, brown hæmatite, Coal-measure sandstone, white, yellow, or purple clay, &c. The sand is obliquely laminated, the bedding-planes sloping towards the north-east, and indicating currents from the south-west. No flints were observed. The mass is only slightly consolidated, and at a little distance looks not unlike Bunter pebble-beds.

Near the words "Avenue Plantation," on the Ordnance Map, about one mile east of Annesley, on the western border of Nottinghamshire, a small gravel-pit discloses about 10 feet of obliquely-laminated, clean, loose sand and pebbles, the lower three feet being clean sand. On this ridge is a conglomerate, regarding the age of which there is considerable divergence of opinion. My remarks refer to the loose sand only. It was deposited upon the top of the hill by currents which appear to have come from a north-westerly direction. The sand contains large and small rolled pebbles of stiff brown Boulder-clay covered by an adherent coating of small pebbles. It is overlain by a thin cake of reddish Boulder-clay. Sand of the same age is also found on the Long Hills, two miles further south. A section about six feet deep is exposed in an old working at the back of the farmhouse. The pebbles are small, and consist of the usual quartzites and quartz, with hæmatite iron-ore, chert and cherty limestone, red sandstone, gritstone, decomposed coal, &c. The dark coaly beds sometimes reach a thickness of several inches.

These sections lie to the north of the northern limit of the dispersion of Cretaceous rocks which took place during the Middle Pleistocene epoch. The absence of flint from the Blackwall and Long-Hills sand might therefore be considered of little value for fixing their ages, were it not for the fact that the currents which formed them passed over areas where flinty gravels are now well developed. A great difference also existed in the direction taken by the ocean-currents of the Older and Middle Pleistocene epochs. At Blackwall and the Long Hills the bedding points with wonderful persistency to currents from the north-west or south-west, while in the southern portions of the Trent basin a flow from the south or even the south-east is indicated. On the other hand, the oblique bedding of the Chalky Gravel indicates indifferently currents from all points of the compass.

Still further to the east, at Gelston, north of Grantham, on the top of the hill, Quartzose Sand is excavated to a depth of about 30 feet. Here and there in the upper portion the sand-beds are cemented into a hard rock. That this hardening took place before the disturbance of the upper portion of the deposit, is made manifest by the way in which the hard beds have been broken up. In the lower portion of the section the sand is finely stratified, and in places contains beds of clay or loam. The pebbles consist almost wholly of quartz and quartzite with a few Coal-measure sandstones. Flints have been introduced into the disturbed surface-portion of the

deposit. Nothing could be more marked than the difference between the Quartzose Sand and the Chalky Sand in this neighbourhood.

South of these sections there are numerous exposures of Older Pleistocene sand, surrounded on all sides or even covered by Middle or Newer Pleistocene flinty deposits, but still preserving their distinctive features unimpaired.

Near Leicester Abbey, in a pit on the river-escarpment to the north-west, the Quartzose Sand is seen passing beneath the Middle Pennine Boulder-clay and Chalky clay. It rests directly upon Keuper marl. The sand is light in colour, splendidly false-bedded by currents from the south-south-west, and almost free from erratic pebbles of any size. The lower nine feet is false-bedded, but in the upper portion the bedding becomes horizontal, and the deposit finally changes abruptly into brown sandy Boulder-clay.

Two sections are to be seen at Aylestone*, south of Leicester, one on the hill east of the church, and the other near the highroad south of the village. Here it has been described as a "fine sand varying from nine to fifteen feet in thickness, false-bedded throughout, marked with streaks of lignite, and containing a few fragments of *Gryphaea* and *Belemnites*."

Other exposures may be seen at Oadby and Wigston. Near Oadby racecourse 9 or 10 feet of light reddish sand rests upon brick-earth, which separates it from the Early Pennine Boulder-clay below. The change from Boulder-clay to brick-earth with morainic masses of Boulder-clay, then to brick-earth with sandy seams, and through a series of interstratified sand and loam-beds into clean false-bedded sand, indicate clearly the changes which occurred between this and the previous stage. The Middle Pennine Boulder-clay and Melton Sand are here quite absent, Chalky Clay having been forced over the sand, contorting, faulting, and tearing it up. One large contortion trends north and south, representing an ice-flow from the east. At Wigston both the sand and the brick-earth are greatly disturbed.

In the Valley of the Wreak the Quartzose Sand crops out from between the Older Pleistocene Boulder-clays continuously for miles on both sides of the river. At Rotherby brick-yard it is seen beneath the Middle Pennine Boulder-clay. Here it occurs as a reddish, stratified, silty, or tolerably clean sand. It contains beds of strong clay in the upper portion and passes down into silty sand or brick-earth. A total thickness of 20 feet was exposed without reaching the bottom. The outcrop of this bed may be traced along the hillsides to the east of Frisby. Several small sections and some tolerably large ones occur along this line. The most important one is to be seen in the village of Frisby itself, near the mill; here it is a light, clean, bedded sand, with occasional pebbly beds; it much resembles the Aylestone sand. The false-bedding indicates currents from the west.

On the north side of the valley the Pleistocene deposits have been

* Transactions of the Leicester Literary and Philosophical Society, 1882-1883.

much cut into by the tributary valleys of the Wreak. The Quartzose Sand may be seen in the north-east corner of the Thrussington clay-pit, in Woldgale Lane, and again at a similar height on the hill to the east, across the Ox Brook. On the road to the east of Brant's Barn, north of Hoby, it has been worked at several points. On the west side of the wood, near Shoby Scholes, north-east of Ragdale, a sand-pit exposes 8 or 9 feet of red stratified sand free from pebbles; it probably reaches a much greater thickness. Pebbles being absent, no certainty can be expressed as to its age; but from its surroundings I am inclined to regard it as Quartzose Sand.

In the railway-cutting near Thorpe Satchville Quartzose Sand is covered by Middle Pennine and Chalky Clay.

Another tolerably large accumulation of Quartzose Sand lies on the more elevated land in the angle formed by the confluence of the Trent and Soar, east of Kegworth. On the west flank of Fox Hill there is a section in about 10 feet of obliquely laminated sand with carbonaceous and gravel-beds. A tolerable percentage of the sand consists of finely comminuted Lias shell-fragments.

Another excavation on the north slope of Mill Hill, just south of West Leake, exposes 15 feet of sand and gravel. Here there are two thick beds of gravel, occasionally cemented into hard conglomerate, separated by a broad band of finely bedded sand.

Half a mile due north of Stanford Hall 20 feet of fine sand may be seen in another pit. In this area, between Mill Hill and Stanford Hall, there are many good sections.

No trace of contemporaneous Mollusca has yet been found in any of these deposits; indeed, in the Trent basin all signs of life are absent, not only in the Quartzose Sand, but in all the succeeding high-level gravels and sands. That the Quartzose Sand may be marine and yet be devoid of molluscan remains will be seen by the distribution of life in the Chalky Sand. In this Chalky Sand the shell-fragments are numerous on the western side of the Staffordshire portion of the Trent watershed, while in the central, southern, and eastern portions of the area they are nearly, if not quite, absent. Now all the sections of Quartzose Sand I have examined are some distance to the east of the westerly watershed of the Trent, and it is highly probable that the cause which led to the absence of molluscan remains from the Chalky Gravel was also the cause of their absence from deposits of Quartzose Sand occurring in the same area.

3. *Middle Pennine Boulder-clay.*

The conditions of climate which gave rise to the formation of the early Pennine glaciers, and which passed away with the increasing submergence of the Quartzose-Sand sea, again returned; for upon the Quartzose Sand there are thick deposits of Boulder-clay, giving evidence of intense glacial conditions.

Like the Early Pennine Boulder-clay, the clay of this stage is almost, if not wholly, free from Cretaceous débris, but frequently

crammed full of Primary rock from the Pennine axis. I have therefore called it the Middle Pennine Boulder-clay.

So far as my observations go, the mass of this clay was formed in the path of the great glaciers which came down the valleys of the Derwent, Wye, and Dove, and crossed the partially submerged valley of the Trent in the direction of the Charnwood Hills. In addition to the ice-stream which came down the northern and western tributaries of the Trent, the press of ice in the Irish Sea seems to have led to the deflection of the Scotch and Cumbrian glaciers into the western portion of the Trent basin; for at Burton-on-Trent there are in the Pennine Boulder-clay erratics entirely foreign to this area.

In dealing with these deposits it must not be forgotten that the advent of such great ice-sheets has so disturbed the floors over which they passed that in some cases almost all traces of arrangement in the earlier sands and clays, or at least the possibility of deciphering them, have been destroyed. I shall therefore be compelled, as I mentioned before, to regard some of what are probably rearranged earlier deposits as belonging to the present stage.

The only section I have seen of Older Pleistocene Boulder-clay containing erratics, probably of Cumbrian origin, occurs on Waterloo Hill, near Burton-on-Trent. There is some difficulty in examining the clay, owing to its position in the section; but its mode of occurrence, colour, &c. all point to an early ice-flow from the north-west.

The village of Spondon, to the east of Derby, is built on the south-west side of a considerable mass of Boulder-clay, shown on the map (fig. 1). The deposit is now only to be seen in section at three points—one in the small ravine excavated by the brook which comes down from Borrowood; another in the road leading to Spondon from the Nottingham road, just beyond the fourth milestone from Derby; and another in Mr. Coxon's brick-yard in the village itself (this brick-yard lies to the north of the Swan Inn). A total thickness of 9 feet is shown. The upper 5 or 6 feet is a light brownish or drab stiff clay, with no signs of bedding, and stuck full of pebbles and boulders of all shapes and sizes. This upper portion contains a few flints and seems to be a disturbed and weathered variety of the main mass of pale bluish or brownish Boulder-clay which lies below. A well sunk in the brick-yard proved the Boulder-clay to be at least 60 feet thick. It maintains the same physical characteristics throughout, and rests upon a contorted surface of Keuper marl and skerry. The clayey matrix, composed chiefly of Coal-measure clay with varying proportions of Keuper marl, is wholly unstratified, and weathers bluish along the joint-lines. The pebbles are chiefly nodules of ironstone, mostly broken up, Millstone-grit, black and white chert with Carboniferous-limestone fossils, Coal-measure sandstone, white and black limestone, and coal. The residue consists of brown quartzites, white quartz-pebbles, hæmatite iron-ore, and various other rocks from the Carboniferous formation. Some of the larger erratics, one of which weighed at least six tons, are

finely polished, striated, and grooved, especially the limestone or hard coal and shale. The larger blocks vary from rounded to sub-angular or angular masses.

Another small patch of Boulder-clay caps the hill north-east of Chaddesden and north-west of Brunswood. In a small ravine which a brook has excavated in the west side of this mass of clay its junction with the Keuper marl may be seen. The stiff blue clay with boulders is contorted and crushed into the clay below, masses of the one being sometimes torn off and buried in the other, while boulders of finely polished and striated Carboniferous Limestone are sometimes found in the disturbed clean red marl itself. A similar section may be seen in the brook coming down from Borrowood. Resting upon, or rather against, the Boulder-clay, and occupying a depression or shelf in the side of the hill upon which Spondon is built, there is a peculiar deposit of gravel of uncertain age. About a quarter of a mile north of the "don" in Spondon on the Ordnance Map, in a field by the stile-road, an excavation shows a section about 50 yards long and 14 feet deep. The stratification is indicated in the upper portion by lines of fine pebbles or gritty sediment, and by the general horizontality. The lower 2 feet contains beds of sand; one lenticular bed, about 8 yards long, consisted of alternations of reddish and yellowish sand, while another was composed of coarser sand, the false bedding of which indicated currents from the west-north-west. These sand-beds contain carbonaceous matter. The pebbles and boulders are of all sizes, generally well water-worn; but many are angular or subangular, particularly the larger boulders. The pebbles are mostly quartzite, chert, gritstone, or Coal-measure sandstone of finer grain. Other Pennine rocks are abundant. The whole deposit is light brown in colour and contains a tolerable percentage of argillaceous matter. Near the surface the gravel is slightly contorted by a force which seems to have come from a north-north-west direction. In this disturbed portion there are a few flints, a rock which is absent from the gravel below. The junction of the gravel with the Boulder-clay is nowhere shown; but no similar deposit was met with, either in the Boulder-clay itself or along the outcrop of the Keuper from beneath it. Of course it may be urged that this gravel is the Quartzose Sand, and the Boulder-clay the Early Pennine; but it presents so many peculiarities that I have not ventured to correlate it with that deposit.

At Sheldon-Wharf brick-yard (fig. 1), south^s of Derby, on the north-west side of the hill, near the canal, is an exposure almost entirely excavated in Boulder-clay. The pit has been worked at two levels: the lower one showed a section of 9 or 10 feet of a loose broken red clay, with dicey pieces of Keuper marl and pockets of sand. The whole mass at a distance very much resembles ordinary undisturbed Keuper. Near the bottom it contains small bits of decomposed gypsum; while bits and patches of variously tinted clay and pockets of light red clayey sand, with occasional small pebbles, are distributed throughout the mass. Quartz and quartzite pebbles and fragments of Carboniferous rock begin to make their appear-

ance towards the top of this portion of the section in tolerable abundance, the matrix at the same time changing to a rusty-coloured sandy clay. The pebbles mostly have their longer axes in a horizontal position. Many of them are finely striated, grooved, and polished. About 5 feet of silty ochreous-brown sand and pebbles separates the redeposited red marl and sandy clay from the overlying Boulder-clay. This consisted of about 8 feet of light-brown stiff clay, purple along the numerous ramifying joints, and thickly studded with pebbles and boulders of various sizes and shapes, mostly beautifully polished, scratched, or fluted. The largest boulder exposed, a mass of Carboniferous Limestone, measured 20" \times 16". The pebbles most numerous are quartzite and quartz, fragments of coal, ironstone, white and black marble, chert, purple Coal-measure sandstone, and Millstone Grit. Many of the pebbles were evidently fragments of larger boulders which had been crushed in transit. Though the deposit shows little or no trace of regular stratification, the boulders are rudely arranged with their longer axes horizontal, and the clay varies vertically in texture in a manner indicative of aqueous action. There was no very marked line of division between any of these beds. All the appearances point to the conclusion that they were deposited in quiet water, local rocks only occurring at the bottom, and foreign materials coming in in greater abundance as the glaciers approached and deposited sand, mud, and boulders in the quiet water.

The high escarpment overlooking the Trent at Hemington is capped by very similar Boulder-clay.

Still further south, south of Long Whatton, is another considerable mass of this Boulder-clay. The high ground south of this village is covered by it. On the north-west it extends from Whatton Rises along the hill for at least half a mile in a south-westerly direction, and covers the whole of the hill-top as far as Oakley Wood and Paradise Hill on the west. There are no sections of any depth to be seen; but at one or two points the character of the deposit is displayed. On Paradise Hill some trenches cut for drainage-purposes exposed a reddish-brown Boulder-clay, with occasional beds or patches of reddish-brown coarse sand containing carbonaceous matter (decomposed coal). The boulders were Carboniferous sandstone and striated limestone, Keuper sandstone, chert, and other Pennine rocks.

This mass of clay is an outlier of the series of deposits cut through during the construction of the Charnwood Railway.

Along the northern edge of the Charnwood Hills, and covering the lower ground through which the railway passes, the country is covered by thick masses of Older Pleistocene Boulder-clay. Though it is very probable that some of these clays were formed by Early Pennine ice, the deposits have been so greatly disturbed and e-arranged by the ice-flow of the Middle Pennine stage, that I shall regard them all as belonging to this stage.

The Charnwood Railway runs nearly due west from Loughborough to Whitwick, along the northern edge of the Charnwood-Forest

rocks. The cuttings made during its construction in 1882 at intervals along the line showed some interesting sections of drift. The ground is composed of low undulations of Keuper, chiefly the Upper Marl, except in the west, where it passes through bosses of Primary rock. The old Forest-rocks rise up from beneath the Keuper to the south of the line.

The cuttings commence about a mile west of Loughborough. The gentle undulations here consist of Keuper marl covered by Boulder-clay and sand, the latter reaching a thickness in some places of 15 feet. At the east end of the cutting it consists of unstratified or silty Boulder-clay resting upon Keuper marl. The rock-fragments, many of which are finely striated and polished, consist of black and white limestone, Coal-measure sandstone, Millstone Grit, Yoredale sandstone, chert, ironstone, coal, Keuper sandstone, and occasional fragments of Lias limestone or fossils. No flints were observed except near the surface. Pockets or masses of sand also occur and increase in number until, when the centre of the cutting is reached, they form a tolerably distinct but highly contorted bed of yellowish-brown laminated sand, with seams of decomposed coal and layers of clay with boulders. The contortions of this deposit are sometimes so marked that the sand-beds are bent over until the proper order of superposition is quite reversed.

A large number of erratics were met with in this cutting at Loughborough Field. The more noticeable of these were as follows:—

	ft.	ft.	ft.
1. Subangular sandstone boulder, deeply fluted	3	2	$\times \frac{1}{2}$
2. Subangular toadstone	1	1	$\times \frac{3}{4}$
3. Angular sandstone	2	$\times 2\frac{1}{2}$	$\times 2\frac{1}{2}$
4. Gritstone	2	2	$\times 2\frac{1}{2}$
5. Mountain Limestone, much grooved, scratched, and polished.....	4	$\times 3\frac{1}{4}$	$\times 1\frac{1}{2}$

The second deep portion of the cutting, passing near Knight Thorpe Lodge, shows few signs of stratification. The Boulder-clay is here an unstratified mass of red clay, with pockets of red sand; it is studded with pebbles and boulders of the rocks found in the previously-described section. Twelve feet was shown, the clay sometimes shading off into Keuper and at other times intensely contorted into it.

The next important section was exposed in the cutting west of Sheepshead Station. The lowest portion of the deposit consisted of a morainic Boulder-clay crammed with boulders, both angular and subangular, of Carboniferous and Triassic rocks. At the west end of the section the whole of the cutting passed through drift, which in the upper portion contained numerous included masses of sand. Indeed the lower portion is a subglacial moraine formed from the debris of older rocks, while the upper portion is a moraine formed by the breaking-up of aqueous Boulder-clay and sand.

The cutting near White-Horse Wood presented an interesting succession of glacial clays and sands. The lowest bed was at the

western end, and consisted of 5 or 6 feet of brown loamy sand, unstratified, and containing very few pebbles, but full of small decomposed bits of coal. This passed up into an unstratified reddish Boulder-clay, full of pebbles and varying from a few inches to 2 feet in thickness. This was succeeded by brown clay with pebbles, but few traces of coal. Resting upon this clay, but occupying the eastern end of the cutting, was 4 or 5 feet of clean red and yellow sand, with dark seams and a few pebbles, and obliquely laminated in parts. There was no marked line of division between the clay and the sand, and the former inoculated with the latter in a manner which left no doubt as to the aqueous origin of the Boulder-clay. No flints were anywhere seen. I have not ventured to correlate this sand with the Quartzose Sand, owing to its local nature.

In the valley of the Soar there are many good sections. At Sileby brick-yard, near the Cemetery, the Keuper marl is covered by about five feet of morainic Boulder-clay with striated rocks.

Still further south, at Thurmaston brick-yard, about 8 feet of brown aqueous Boulder-clay rests upon the marl. It is full of striated rock-fragments, chiefly Lias and Trias, but Carboniferous limestone, sandstone, and ironstone also occur. The boulders lie horizontally in the clay, which here contains interstratified beds of sand and loam. At the west end of the pit the deposit becomes quite gravelly, and the beds of loam, gravel, and Boulder-clay have been forced over the underlying marl, which is much crushed and contains streaks of sandy clay intruded from above.

At the Leicester-Abbey section the intensely false-bedded Quartzose Sand becomes horizontally bedded in the upper four feet, and then changes suddenly into brown or reddish-brown Boulder-clay. We have here indications that the rapid currents of the Quartzose-Sand stage disappeared on the approach of the Middle Pennine ice, an effect partly caused perhaps by a decrease in the depth of the submergence.

Mr. Beasley's sand-pit at Aylestone, south of Leicester, though showing great signs of ice-action, is yet sufficiently undisturbed to show the arrangement of the sands and Boulder-clays. Here the Quartzose Sand is succeeded by a reddish Boulder-clay containing Charnwood, local, and Pennine rocks. The one deposit graduates into the other without signs of disturbance, the change from sand to Boulder-clay being due to change of sediment and the absence of strong currents. The Charnwood boulders occur chiefly near the junction of the clay with the sand, especially the large boulders, an arrangement pointing to the action of local glacial conditions in the Charnwood Hills. It would seem that before the actual approach of the main Pennine ice-flow local Charnwood glaciers sent out ice-bergs, and coast ice distributed their burdens upon the bottom of the surrounding sea in which the muddy sediment was collecting. The section I am now referring to has been very much disturbed by the ice of the Great Chalky Boulder-clay stage, for great masses of the lower sand have been torn up, thrust upon the Middle Pennine clay, and mixed up with the Chalky clay which occurs above.

Though the Middle Pennine Boulder-clay covers large areas in

the Wreak valley, where it rests upon the Quartzose Sand, the only exposure to be seen is in the brick-yard at Rotherby. Here it forms the upper portion of the ridge which extends in the direction of Kirby Bellars. It is a silty tough clay full of boulders ranging in age from Lias to Carboniferous.

I am indebted to Mr. J. J. Harris Teall and to Mr. J. Shipman for a description of the sections which were exposed in the railway-cuttings between Melton Mowbray and Nottingham. Though there is no absolute certainty that the whole of the deposits occurring beneath the Chalky clay, now to be described, belong to this stage, yet, in the absence of direct proof to the contrary, I shall consider them here.

In the cutting at the mouth of the Stanton-Hill tunnel the Teagreen Marls are covered by black Rhætic shales which have been thrown into zigzags, gradually diminishing in acuteness as the eye follows them down to the bottom of the section. These crumplings could be seen on both sides of the line, and it was clear from their trend that the ice-sheet which produced them must have come from the north-west. The Paper Shales are largely mixed up and redeposited with a brown sandy Boulder-clay which rests above. To be more accurate, this drift consists of a matrix of stiff bluish or purplish-brown Boulder-clay, evidently very largely derived from the grinding down of Lias, and Rhætic and Keuper marl. It was full of lumps and fragments of the same rocks, Lias being most plentiful, along with pebbles of quartz, pieces of fibrous gypsum from the Upper Keuper, boulders of Millstone Grit, encrinital limestone, and Coal-measure sandstone, all mixed together in the most confused manner. Many of the rock-fragments were smoothed and polished, and some distinctly striated. One of the boulders, a mass of Millstone Grit, stood three feet in height, and was more than eleven feet in circumference. The drift shows little or no signs of stratification, and has evidently been subjected to immense lateral pressure from a north-westerly direction. Resting upon this Boulder-clay, and probably, like the mass in the Aylestone section, torn up from the Quartzose Sand, come about 14 feet of loose reddish-brown sand with pebbles and occasional false-bedding. The whole mass showed signs of having undergone considerable lateral pressure, and the contortions could be clearly traced in the deposit of sand by the tortuous bedding of the strings of pebbles in it. These two deposits, the brown Boulder-clay and sand, were confined to the north end of the tunnel, and contained no traces of recent shells.

In the Plumtree cutting there is similar sandy Boulder-clay, but it had been greatly disturbed by the Chalky Clay, a small thickness of which capped it.

III. MIDDLE PLEISTOCENE EPOCH.

1. *Melton Sand.*
2. *Great Chalky Boulder-clay.*
3. *Chalky Gravel.*

The deposits formed in the Trent basin during the Middle Pleis-
Q. J. G. S. No. 168.

tocene epoch, regarded in the light of our knowledge of earlier ice-action in the same area, indicate that very important physical changes must have taken place towards the close of the previous epoch—changes which led to the advance of an ice-sheet from a direction markedly different from all previous ice-flows, and the introduction of an entirely new series of rock-fragments into the Trent basin. The earlier glaciers all originated in the Pennine or other British hills, and spread their *débris* over the surrounding low lands; but during the epoch I am now about to notice, the ice advanced from a north-easterly direction, and for the first time spread over Central England the outcropping rocks it successively encountered. The Boulder-clay with chalk and flint thus spread over the country has been called, from the immense quantities of Cretaceous rock it contains, the Great Chalky Boulder-clay.

Although I have divided this epoch into three stages, I do not mean to affirm that there is any break between them indicating lapse of time. Indeed the deposits may be seen to pass without the least unconformability one into the other.

In West Staffordshire the gravels and sands frequently contain fragments of marine mollusca, especially on the western side of the watershed. The marine deposits with flint, in this part of the area, probably represent the whole Middle Pleistocene series, including the Great Chalky Boulder-clay. According to this view the latter deposit was not formed in the open water then spreading over the west of England.

It is mainly, if not wholly, due to the introduction of Cretaceous rocks into the Trent basin at this stage that it is possible to classify the Boulder-clays and divide the deposits of the Pleistocene period into distinct lithological groups.

Although the peculiar character of this north-easterly ice-flow has been noticed by many geologists, so far as I am aware, no one has suspected that it formed an abnormal episode in glacial history. Professor James Geikie, to account for 'the peculiar direction of the ice-flow, has advanced the hypothesis that the Pennine glaciers were brushed aside by the advancing Scandinavian ice, which, sweeping over England from the north-east, distributed the flints and chalk of Lincolnshire and Yorkshire over central England. Mr. Searles V. Wood, on the other hand, maintained that the direction of the ice-flow was due rather to a change in the inclination of the country. The attitude I have assumed towards these two theories has been dictated more by the actual succession of the deposits, as I have found them in the field, than from any inherent weakness in the theories themselves to account for the dispersion of the boulders under certain conditions. Assuming that the Scandinavian mountains existed in their present form in older Pleistocene times, how was it that the glaciers of this early period from the Pennine Chain were sufficiently powerful to entirely shut out from this part of England an ice-flow from the north-east similar to the one which at a later stage formed the Great Chalky Boulder-clay? Again, the occurrence of Middle Pleistocene gravel and sand, containing chalk

and flint, immediately above and below, or even interstratified with, the Great Chalky Boulder-clay, points to the conclusion that the ice-sheet of this stage did not enter a district already occupied by Pennine ice, but, on the contrary, entered what was then comparatively open water in the Trent basin. The difficulty therefore is, not how the north-easterly ice advanced into this neighbourhood, but rather how we are to account for the absence of glaciers flowing from the Pennine Chain. From these considerations it appears most probable that the Pennine Chain was much lower during the Middle Pleistocene epoch than it was when the older Pleistocene Boulder-clays were formed, and that the Great Chalky Boulder-clay advanced into the partially submerged area of the Trent basin.

The Great Chalky Boulder-clay is generally a true ground-moraine, but in some places, such as Chellaston, Melton Mowbray, Market Bosworth, Abbots Bromley, &c., it presents indubitable signs of aqueous action.

When the glacier of this epoch melted away, the country was left submerged to a considerable depth beneath the ocean. Gravels were then formed upon the Chalky Clay and other exposed rocks, especially upon the southern and western watershed of the Trent basin, where the Atlantic beat upon the islands, and surged through the straits or over the shoals. The same phenomena exist in the central portions of the Trent basin, but, probably owing to the land-locked nature of the area, they do not reach such a great development. These gravelly deposits, which I have called the Chalky Gravel, contain a great variety of rock-fragments derived from the Chalky Clay or adjacent rocks. In many instances chalk, both as pebbles and sand, forms no inconsiderable percentage of the deposit.

1. *Melton Sand.*

The Melton Sand occurs very sparingly between the older rocks and the Great Chalky Boulder-clay. The deposits of this stage dealt with were formed within the watershed of the Trent in a sea of tolerable extent and depth, probably connected with the ocean by straits to the westward. The land-locked, and probably ice-locked, nature of the Melton-Sand sea did not favour the formation of much clean false-bedded sand. The Melton Sand consists chiefly of stratified sand, with occasional beds of gravel or loam. A stray flint may be sometimes found in some of the older Pleistocene gravels or Boulder-clays, but in the Melton Sand they suddenly make their appearance in great numbers for the first time.

Unfortunately no section has yet been found showing the passage of Older Pleistocene Boulder-clay into Middle Pleistocene sand. Indeed there appears to have been somewhat of a break between these two epochs, perhaps partly due to temporary elevation and subaerial denudation. This break, which partakes of the nature of an unconformity, is clearly shown in many sections.

At Leicester Abbey the brown Middle Pennine Boulder-clay is separated by a marked line of division from the Chalky Clay above.

A much greater lapse of time is indicated by the unconformity at Oadby; for here both the Melton Sand and the Middle Pennine Boulder-clay are absent, the Chalky Clay resting upon a highly contorted surface of the Quartzose Sand.

At Wigston the Chalky Clay has also been thrust upon Quartzose Sand, while at Aylestone it has been forced over the Middle Pennine Boulder-clay as well, contorting and ploughing up both deposits. A similar explanation is perhaps applicable to the sand and Boulder-clay met with at the northern entrance of the Stanton tunnel, on the Nottingham and Melton Line.

In the great majority of cases the Chalky Clay rests directly upon a highly disturbed surface of older rock.

As it is in the neighbourhood of Melton Mowbray that the deposit is typically developed, I have called these sands, gravels, and loams, the Melton Sand. They are interstratified with the sedimentary Boulder-clay forming the base of the Chalky Clay. Indeed, as I have said before, there is no break in the Middle Pleistocene epoch indicating lapse of time, the divisions into stages being made for convenience of treatment, and to emphasize the fact that the ice of the Chalky-Clay stage advanced over a submerged area in this part of Britain.

At Melton Mowbray, in the brick-yards on the north side of the town, were to be seen interstratified beds of sand and brick-earth, containing flint, chalk, Oolitic limestone, &c. According to Professor Judd, the brick-earth and sand is "overlaid by ordinary Boulder-clay, which here attains a thickness, as proved by well-sections and borings, of not less than 200 feet." I did not in this case see the Chalky Clay resting upon the Melton Sand, but there seems to me to be little doubt as to the correctness of Professor Judd's statement. When I visited the Melton sections, the more southerly of the two was almost wholly excavated in these stratified beds. At the bottom is a dark silty clay with pebbles; it breaks up into small angular fragments, and contains Triassic, Carboniferous, Jurassic, and Cretaceous rocks in abundance. Resting upon this pebbly brick-earth comes a bed of light-coloured sand, almost free from pebbles, but rather coarse in places. The whole is highly contorted. These contortions and the deposits they affect are of different age from those beds of disturbed flinty gravel which formed the upper 7 or 8 feet of the section. The lower sand and clay were exposed to a depth of about 15 feet.

In a clay-pit a little further to the north may be seen the same sedimentary Boulder-clay.

Still further south, at Asfordby, the light yellow or grey sand is 15 feet thick. It contains dark seams, and pebbles of flint, hard chalk, Oolitic and Lias limestone, &c. It shows signs of great disturbance, and appears to be covered by brownish Chalky Clay.

A similar deposit was seen at Grimston in a temporary excavation; it is here within 30 feet of the present Wold top, indicating a very considerable submergence.

South of the river Eye, at Eye Kettleby, stratified sand, about 8 feet

thick, rests upon flinty gravel. The sand is false-bedded, and contains carbonaceous seams. Brown Chalky Clay rests unconformably upon it. The sand shown in a pit at Burton Lazars may also belong to this age.

On Chellaston Hill, resting upon Keuper marl and passing upwards into the Chalky Clay, there are gravelly and sandy beds of an aqueous character. They are exposed in the plaster-pits on the south-east side of the village. At the south end of the main cutting they are well shown.

Mr. J. W. Eardley, of Derby, has also kindly furnished me with a description of the deposits passed through by some borings on Chellaston Hill (see fig. 3, p. 460). Two deep shafts were sunk through the Chalky Sand and Chalky Clay into the sandy beds below. After passing through the upper sand, and then through from 40 to 45 feet of Boulder-clay, the shaft entered six feet of running sand, then six feet of loam, next loam and sand two feet, and then another two feet of gravel which rested upon Keuper marl with gypsum.

2. *Great Chalky Boulder-clay.*

We now come to perhaps the best-known of all glacial deposits, the Great Chalky Boulder-clay.

No attempt will be made to follow it out of the Trent basin, or to give a detailed description of its distribution; my intention is rather to note its general mode of occurrence, its position among the deposits of the Pleistocene period, and the probable method of its formation.

One of the greatest obstacles to a just appreciation of the laws which regulate the formation of Boulder-clays has arisen from the difficulty of determining the exact relative ages of the deposits dealt with, and the idea, perhaps unconsciously adopted, that the boulders they contain were always derived directly from their parent rocks. For instance, the accumulation of Boulder-clays and sands encumbering the Liassic ridge between South Nottinghamshire and Leicestershire has been regarded as belonging to one stage of the Pleistocene period. In this particular area the main mass of the Chalky Clay really lies to the north and east of the ridge, and has been thrust against and partially over earlier Boulder-clays and sands. Indeed, the presence of tolerably high land in the path of the advancing glacier which moved up the Trent valley has to a great extent stopped the further westerly extension of typical Chalky Clay. Roughly speaking, the chalky débris was forced up the Trent valley for some distance and then spread out in two long tongues—one extending up the main valley as far at least as Hanbury, north-west of Burton-on-Trent; and the other over the district south of the Wreak, past Leicester, and then along the southerly margin of the Trent basin. How far it extends in this direction I cannot say. The intermediate area of the Ashby-de-la-Zouch coal-field owes its freedom from the typical or morainic Boulder-clay of this

stage to the shelter afforded it by the high land to the east and north. In this area the Chalky Clay is a silty deposit with a few flints and quartz or quartzite pebbles.

In addition to the evidence furnished by the presence of great numbers of Cretaceous boulders in the Chalky Clay, an indication of the direction of the ice-flow of this stage has, in one instance at least, been left upon the rocky floor over which it moved. In the Stanton tunnel, south of Nottingham, Mr. Teall found the Lias limestone, upon which the Chalky Clay rested, striated from the east-north-east to west-south-west.

The Pennine rocks in this Boulder-clay have been derived from the Older Pleistocene deposits over which the ice passed. If we regarded them as having been derived directly from the Pennine Chain we should be forced to admit an ice-flow from this direction as well—an inference totally at variance with the distribution of the Boulder-clay and its associated deposits.

The abnormal direction of the ice-flow most probably owed its existence to a period of intense cold coupled with a considerable depression of the Pennine axis. This would result in the approach of Continental ice without the interference of local English glaciers.

When I come to treat of the Chalky Gravel, it will be seen that I regard the gravels in the west of Staffordshire as representing all the Middle Pleistocene stages, the Great Chalky Boulder-clay never having been formed in the open water then existing on the west side of the watershed.

Upon the Melton Sand the subglacial streams deposited silty sandy Boulder-clays in the partially land- and ice-locked valleys of the east of England. In the majority of cases these sands and silty Boulder-clays, together with older deposits, have been overridden and converted into unstratified moraine.

Although, as we have seen, the Great Chalky Boulder-clay is extensively distributed over the country and sections of it are of tolerably frequent occurrence, it generally maintains such a wonderfully uniform lithological character that a description of all the sections would involve constant repetition. I have therefore confined myself to sections where its relationship to deposits of other stages is shown, or where it presents peculiar characteristics. In the previous stage those sections which show the passage of the Melton Sand into Chalky Clay have been noticed. As these sections throw considerable light upon the formation of this Boulder-clay, I propose to state briefly the opinions at which I have arrived.

The late Mr. Searles V. Wood contended that the Great Chalky Boulder-clay was formed by an ice-sheet depositing and overriding the mud-bank which it formed at its seaward face. I am inclined to support a somewhat similar view in preference to the theory which attributes its formation wholly to land-ice. The presence of stratified sand and gravel at its base is evidence that the Trent basin was submerged when the ice-sheet advanced over it. It has been argued that the absence of molluscan remains is conclusive evidence against its aquatic origin. This is, no doubt, a difficulty ;

but I would suggest as an explanation that the brackish state of the water in the partially land- and ice-locked sea was inimical to marine life.

The stratification met with in most rocks resulted from intermittent current-action and the consequent irregular supply and deposition of material. On the other hand, in the aqueous Boulder-clays, owing to the constant nature of the supply of mud brought down by subglacial streams, and the absence of strong currents, the sedimentary nature of the deposit is not so well marked.

When the glacial conditions of this stage reached a maximum, the greater part of the Trent basin was occupied by ice, the immense weight of which ground up the subglacial floor and converted much of the earlier stratified Boulder-clay into unstratified moraine. Not only did it rearrange earlier Boulder-clays, but in many places it formed its moraine almost entirely from the older rocks themselves.

The most north-westerly outlier of the Chalky Clay with which I am acquainted occurs at Abbots Bromley. In a pit south-west of the town, about 15 feet of silty clay, with occasional sand-partings or beds of strong clay, passes up into stratified sand with flints and quartzite pebbles. This silty clay, which is almost free from pebbles or boulders, covers a very considerable area in this neighbourhood and is exposed at several other points.

At Hanbury Woodend, north-west of Burton-on-Trent, typical morainic Chalky Clay is covered by Chalky sand, and rests upon what appears to be Quartzose Sand. The Boulder-clay lies unconformably upon the lower sand and reaches a thickness of about 9 feet; it contains chalk and flint in abundance, together with quartz and quartzite pebbles, Carboniferous limestone, &c. Mr. Molyneux* has noticed what he describes as a remarkable trail of chalk-flints "stretching across the high grounds of Hanbury Woodend running east and west." He also describes many other sections, now obscured by talus, and traces the drift, which sometimes reaches 90 feet in thickness, over considerable areas.

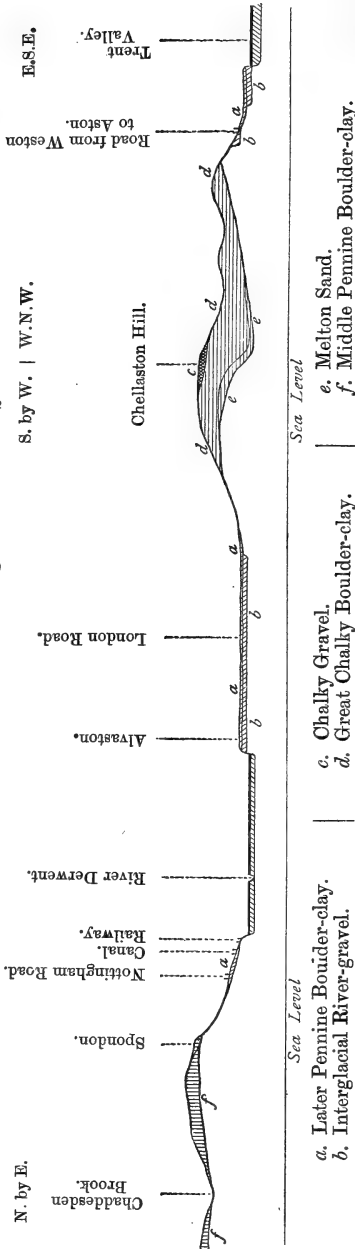
What appears to be Chalky Clay occurs in the Dove Valley at Oak Green brick-yard, N.N.W. of Sudbury. It is here a blue clay, somewhat similar to that shown at Abbots Bromley, with seams of coarse sand, occasionally gravelly. A few flints were found in it.

The next outlier, and the largest I have found north of the Trent, occurs near Chellaston (figs. 1 and 3), where it fills up an old valley and caps the hill-top. In this sheltered spot the Chalky Clay is of a decidedly sedimentary character, and has to a great extent escaped the grinding-action of the ice. Though this sedimentary condition of the deposit is very clearly shown in most of the sections near Chellaston, traces (sometimes very obvious traces) of ice-action are to be seen.

At the south end of the main working, near the outcrop of the gypsum bed, and lying upon the sandy deposits which have been described, comes about 12 feet of purple silt containing glaciated boulders. The boulders, which generally lie with their longer axes

* Burton-on-Trent; its History, its Waters, and its Breweries.

Fig. 3.—Section through Spondon Hill and Chellaston Hill in the line shown on the Map, p. 438. Vertical scale, 1 inch = 500 feet; length of section 7½ miles.



horizontal, range in age from Carboniferous to Cretaceous. Carboniferous rocks are not so numerous as they are in the sand below; they have been derived, not directly from their parent rocks, but from the older Pleistocene Boulder-clays.

At the north end of the cutting the Boulder-clay was exposed to a depth of about 20 feet.

Good sections were also at one time to be seen in the Chellaston railway-cutting, near the junction. Here the upper 5 feet is a brown pebbly clay, highly contorted and resting upon dull, stiff, purplish, silty, compact clay, which is also studded with pebbles and boulders. Interbedded with the purple clay are seams and pockets of soft brown sand containing minute pebbles of coal and hard chalk. Smooth and rounded boulders are common. In some spots the drift consists of stiff dark clay, with boulders stuck in it at all angles, and showing no trace of aqueous action. This, however, is by no means the rule, for the clay is generally a silt, and in some places showed distinct stratification. Large boulders of Carboniferous limestone and Coal-measure sandstone occur, but they are not plentiful. In the upper contorted surface portion are gravelly beds composed almost entirely of rounded chalk pebbles and bits of flint. The blue clay passes down into brown silty Boulder-clay, and in the cutting nearer the station it overlies a thin bed of gravel.

East of Chellaston the Great Chalky Boulder-clay is not met with again until we come to the extensive mass almost covering the high ridge between South

Notts and Leicestershire. Here the Chalky Clay may be seen in its intensely chalky condition, and also as a silty clay with striated boulders and beds of sand.

Good sections were exposed in the cuttings on the railway between Nottingham and Melton Mowbray. Mr. J. J. Harris Teall has kindly allowed me to make use of some notes he made when the work was in progress. To these notes I have been able to add some by Mr. Shipman.

Resting upon deposits of rather uncertain age, which have been described as Middle Pennine Boulder-clay, there occurs, at the mouth of the Stanton tunnel, a deposit of unstratified Boulder-clay with chalk and flint, thickening to 70 feet in the centre of the tunnel, where it rests upon a splendidly striated floor of Lias limestone, indicating an ice-flow from east-north-east to west-south-west. At the south-south-east end the tunnel was entirely in this deposit. Similar clay formed the uppermost member in the Plumtree cutting. This deposit is evidently the Great Chalky Boulder-clay, the ice of which age first passed over and striated the Liassic floor and then heaped upon it 70 feet of morainic Boulder-clay. South of the Stanton tunnel the rock-fragments in the clay become much more varied in character, and show an arrangement from north-west to south-east, similar in order to that of the outcrop of the rocks from which they have been derived. For example, in the north-westerly cuttings Keuper marl, Rhætic shale, and Lias rocks abound; but as we work south, Middle Lias, Oolitic limestone, and Cretaceous rocks appear in increasing profusion, an arrangement evidently due to the ice advancing roughly along the strike of the rocks. Still nearer Melton Mowbray, at Grimston, Chalky Clay rests upon bluish silt and Melton Sand. Similar deposits are exposed in the railway-cuttings near Asfordby. These sections have been described under the Melton Sand.

Near Mount Sorrel the Chalky Clay rests upon a mamillated rocky surface. In many cases the rocks beneath Boulder-clays, especially the softer kinds, are broken and forced out of position instead of being smoothed or striated.

At Leicester Abbey morainic Boulder-clay rests upon Middle Pennine Boulder-clay, from which it is separated by a sharp line of division.

At Oadby and other places in the neighbourhood, the Chalky Clay has been forcibly driven over the Melton Sand, contorting or ploughing up large masses of it. The action of the ice-sheet has here been to crumple the sand into folds trending roughly from north to south, and indicating an ice-flow from the east.

At Mr. Beasley's sand-pit to the south of Aylestone, the uppermost member is a blue clay with flints, &c.; it has been forced over the underlying Middle Pennine Boulder-clay and Quartzose Sand with which it has been incorporated.

Around Market Bosworth the Chalky Clay is exposed at several points and presents much the same appearance as at Abbots Bromley. At Shenton, near the railway, a brick-yard exposes about

20 feet of strong clay with concretions and beds of sand. The clay is laminated and, like the sand, is free from boulders. The whole deposit is much disturbed, the sand-beds sometimes standing in a vertical position. Near Market-Bosworth station, in another excavation, the sandy clay becomes stony towards the bottom. Pebbles of quartz, flint, sandstone, coal, and shale were seen.

3. *Chalky Gravel.*

Resting upon the Great Chalky Boulder-clay or older rocks, and spreading in great sheets or banks along almost the entire length of the Trent watershed or intervening high lands, there are thick deposits of stratified, flinty, or chalky gravel or sand. Unlike the older Quartzose Sand, the current-bedding in these deposits as frequently slopes to the east as to the west. Along the western portion of the watershed and in areas where the Chalky Clay is absent, the gravel loses its intensely chalky character and rests directly upon the older rocks, the Great Chalky Boulder-clay having apparently entirely thinned out in this direction. To what extent the Chalky Gravel may, in part, be equivalent to the Melton Sand in these westerly sections I cannot say.

It will be most convenient first to follow the Chalky Gravel in a westerly direction from Lincolnshire and Leicestershire, across that portion of the Trent basin which lies to the south of the river, and then through Nottinghamshire and Derbyshire into Staffordshire. By so doing, the Chalky Gravel will first be seen, with few exceptions, in its intensely chalky condition resting upon or in the immediate vicinity of Chalky Boulder-clay. In the northern and western division it usually overlies older rocks and contains little or no chalk, but numerous flints.

The occurrence of the Chalky Gravel not only upon the Chalky Clay where it is thickest, but also upon the flanks of the hills, or even resting upon the older rocks at low elevations in the wider valleys, proves that though the Chalky Clay has been denuded from considerable areas, it was by no means deposited as a uniform layer over the whole district. Indeed some portions of the main valleys have always been quite free from it.

On the high lands of Lincolnshire and Leicestershire the Chalky Gravel was evidently deposited in the sea and exposed to the action of currents and icebergs, or even to the temporary readvance of the glacier which formed the Chalky Boulder-clay.

The officers of the Geological Survey* regard some gravel which occurs south and south-west of Coddington, near Newark, as of interglacial age. I have not been able to find any good sections exposing the deposit; but from what could be seen in old workings, I am inclined to regard this view as correct, and relegate it to this stage.

Two miles south of Grantham clean, current-bedded, Chalky sand

* Memoir on the Geology of the south-west part of Lincolnshire.

and gravel, frequently cemented into hard masses of rock, passes horizontally into gravelly rubble. Here, and wherever the gravel rests upon Chalky Clay, it contains a great assortment of rocks from that deposit.

Mr. Skertchly has noticed the same gravel near Saxby, Frisby, and Garthorpe. These exposures are now partly grass-grown, the only one to be seen being to the west of Garthorpe church. He says, "at Saxby there are large pits dug in gravel which appears to be intercalated in the Boulder-clay. The pits are about twenty feet deep, and the material, which consists of irregular beds of gravel and sand, is very much contorted. It is mainly composed of pebbles of the Lincolnshire Limestone; of other rocks, Coal-measure sandstone and small rounded pebbles of Northampton ironstone are abundant, as are also nodules of ironstone from the Lias clays; flints occur sparingly, as also do pebbles of quartzite. The stones vary in size from boulders a foot in diameter down to small grains. The sand is for the most part siliceous." Although this gravel is regarded as being intercalated in the Boulder-clay, the evidence appears to me more to favour the view that it is contorted into the upper surface of that deposit.

At Tilton, one of the highest points in east Leicestershire, near the windmill, a pit exposes a section of the Chalky Gravel. The sandy and gravelly beds are well stratified, and have been forced into a vertical position or even thrown quite over.

Similar deposits may be seen at Billesden, on the road leading to the Coplew, and also near the mill.

At Skeffington there are two sections—one near the village, and another at Brooms Wood. East of Tilton, at Halstead, is a good section. Two pits near the road leading from Knossington to Somerby have also been excavated in the Chalky Gravel. Sections may also be seen at Cold Overton, Burrow on the Hill, Thorpe Satchville, and Stoughton. Many of these show beds of loam interstratified with sand and gravel.

Near the church, at Barrow-on-Soar, a rather peculiar section is shown. Resting upon Lias shale is a bed of mottled red, gravelly, sandy clay, varying from four to five feet in thickness. Upon this comes eighteen inches of loamy clay containing lenticular beds of reddish stratified sand. Upon this rests gravel with seams of sand. Horizontally bedded red loamy sand covers the whole. Flints and quartz or quartzite pebbles are numerous throughout the whole depth of the section.

South of Leicester a great number of sections may be seen. At Blaby Wharf about twenty-one feet of false-bedded Chalky Gravel rests upon Chalky Clay; it contains great quantities of hard chalk, flint, and other easterly rock-débris, derived from the Chalky Clay. Small grains of chalk form no inconsiderable portion of the sand. Many of the beds are blackened by carbonaceous matter, and small lumps of decomposed coal are numerous. The false-bedding indicates currents from the east and west. Rolled boulders of pebble-covered Chalky Clay are of frequent occurrence.

Similar sections may be seen at Kilworth, Smeeton, Saddington, Shearsby, Bruntingthorpe, Husbands Bosworth, Sibbertoft, &c., &c. At Sibbertoft it is consolidated into stony masses five feet in thickness. By far the finest section is, or was, to be seen in the railway ballast-pits at Kilworth, a few miles south of the Trent basin. The section was several hundred yards long and about thirty-five feet deep. The gravel was generally stratified in beds of varying degrees of coarseness and contained numerous false-bedded layers of sand and seams of loam or clay. In the greater number of instances the oblique bedding pointed to currents from the east or north-east. The pebbles were mostly well rounded. Here and there an angular boulder occurred, stuck on end, as though it had been dropped there, or the gravel lost all traces of bedding and presented a mere jumbled mass of stones and sand. Cretaceous and Jurassic débris were most plentiful, but Coal-measure sandstone, black and white Mountain Limestone, grey granite, and other rocks were to be seen. One mass of granite measured $2' \times 2' \times 1'5$; a boulder of Carboniferous Limestone $1' \times 1' \times 1'$, and one of gritstone $2' \times 1' \times 1'$. Quartz and quartzite pebbles were scarce.

To what extent the Chalky Gravel is spread over the northern portion of Warwickshire, I have been unable to ascertain.

In the Ashby-de-la-Zouch coal-field it is tolerably well developed.

South of Ravenstone a good section, about 10 feet deep, exposes stratified flinty gravel.

In the neighbourhood of Market Bosworth the high plateau to the east and south is covered by gravel resting conformably upon silty Chalky Clay almost free from pebbles. There are several sections—one just north of Market Bosworth, another about one mile south of Cadeby, a third north of Shenton, and a fourth south of Sutton Fields. On the hills south of Sutton Fields there is about twenty feet of typical Chalky Gravel. The deposit is light in tint, false-bedded, and contains flints in the pebbly beds.

On the south-easterly spurs of the Pennine Chain the Chalky Gravel is not extensively developed, but it becomes more plentiful in a westerly direction. In Nottinghamshire flinty gravel may be seen near Blidworth, and at other points, resting upon the sandstone.

South of Nottingham, on Wilford Hill, there is about 20 feet of gravel and sand, but no sections are shown.

In Derby (fig. 1) a patch of stratified gravel with flints is exposed by an excavation in Green Lane. This deposit and another near the Arboretum very probably belong to the Chalky-Gravel stage.

On Chellaston Hill (fig. 1) the Chalky Boulder-clay is capped by gravel reaching a thickness of at least 17 feet, and covering an area of about a quarter of a square mile. A section may be seen on the west side of the stile-road leading from Chellaston to Weston. The sand is clean, stratified, yellow or reddish brown in colour, and contains flints and quartz pebbles. The section fig. 3 (p. 460) passes through this deposit.

South of Ashbourne, on the high land, gravel is of tolerably frequent occurrence. In most cases the deposit is very much disturbed, signs

of stratification being seen only in the lower portions of the sections, which are scarce.

West of Chellaston the most typical deposit of Chalky Gravel rests upon the outlier of Chalky Clay at Hanbury. In this section the gravel is intensely chalky and contains numerous flints and other eastern rocks. Here and there the gravel is cemented into hard masses similar to those met with at Sibbertoft and to the south of Grantham; it is banked against the Chalky Clay and what is probably the Quartzose Sand.

In most of these easterly sections the gravel has been greatly disturbed, especially where there is open country to the east or north-east. Though a considerable amount of this disturbance has evidently been due to more modern glaciers, in some instances the evidence points to contemporaneous ice-action in the form of bergs and glaciers. The more westerly sections, especially those facing the western sea, though disturbed or even covered by later Boulder-clay, have evidently been formed in open water, and contain the remains of numerous species of Mollusca.

South and west of Uttoxeter sections of gravel are exposed at Bramshall, Crabtree House, Bagots Wood, Bagots Bromley, &c.

In the neighbourhood of Abbots Bromley a considerable sheet of stratified sand and gravel with flints rests upon silty clay. In this respect it closely resembles the Market Bosworth deposit. Several sections may be seen north and west of the town.

North of Stone, in a brick-yard, there is an interesting face of Chalky Gravel, about six feet deep. It rests upon Keuper marl. The sand is a well-stratified clean deposit with beds of gravel containing flint.

The most north-westerly point at which I have seen the Chalky Gravel is in the Biddulph Pass leading from the Trent basin into the Cheshire plain. So far, no contemporaneous molluscan remains have been noticed, but no sooner is the western watershed reached than they are to be found in great plenty both in the passes and on the western or Atlantic side.

At Biddulph, near the station, at the summit of the pass, is a deep section. The sand is tolerably free from pebbles. The oblique bedding points to currents from the south-south-east, south-west, or even from other directions. Flints are by no means scarce, considering the scarcity of pebbles of any kind. If anything, they are more numerous in the upper than in the lower portion of the section. The sand is light in tint and contains dark seams of decomposed coal. Carboniferous rocks furnish the majority of the pebbles other than quartz, quartzite, and flint. In some of the gravelly beds shell-fragments are not uncommon. From here the sand extends down the pass until it joins the main sheet in the Cheshire plain. Good sections are to be seen in Wragg Street, Congleton, and also in the brick-yard near the canal.

Along the western side of the watershed, between Silverdale and Congleton, many good exposures are to be seen. One of the largest is just west of Alsager Station. It is worked to a depth of at least

thirty-five feet. The sand is clean, stratified, and current-bedded, the more gravelly beds containing flints and shell-fragments.

At Keel, south of the Silverdale Pass, on the watershed, and again in the pass itself, at Little Madeley, the same gravel is exposed. At Little Madeley it is eight or nine feet thick, contains sand-beds and rests upon sand. It contains numerous Palæozoic pebbles, flints, and shell-fragments.

Sections in similar gravel have been opened out near Eccleshall.

The sand and gravel with shell-fragments and flints occurring below the Boulder-clay at Wolverhampton, I also regard as Chalky Gravel.

Referring to these deposits, the Rev. W. S. Symonds says * :—
 “There are fossiliferous sands and gravels near Bushbury Hill, which were excavated during the railway-cuttings, and from which the Rev. W. Lister obtained a series of shells similar to those obtained by Mr. Marr near Buildwas, on the Severn. Among them were *Astarte arctica*, *Cyprina islandica*, *Nassa*, *Turritella*, *Purpura*, and many others common to our British Seas.”

IV. NEWER PLEISTOCENE EPOCH.

1. *Interglacial River-gravel.*
2. *Later Pennine Boulder-clay.*

The evidence furnished by the deposits of the two previous epochs favours the assumption that, up to the close of Middle Pleistocene times, the area under consideration was uninterruptedly submerged to a greater or less extent. We have also seen that during the Older Pleistocene epoch the glaciers originated in our British hills; whereas during the succeeding epoch they advanced over the country from the north-east almost regardless of local contour. If any interruption did occur in this submergence it was in the interval which separated these two series.

The deposits of Newer Pleistocene age now to be considered indicate the first signs of subaerial erosion and the consequent formation of river-gravel, a state of things which has, with the interpolation of one or perhaps more cold periods, existed to the present day.

During this stage the rivers cut down their valleys through the older Boulder-clays and sands to within about twenty feet of their present depths, and left their gravels stranded as terraces at various heights above their present courses.

Upon these interglacial gravels, or upon the older rocks, there frequently rests a Boulder-clay, sometimes reaching a considerable thickness. The rock it rests upon is always much contorted or broken. Unlike the earlier Boulder-clay it is conformable to the surface-features produced by the subaerial erosion of the previous stage. The direction of the ice-flow and the nature of the erratics

* Records of the Rocks.

distributed over the face of the country indicate a period of cold during which glaciers came once more from the Pennine Hills. The erratic boulders of this stage distributed over the westerly portion of Staffordshire show that the climate was sufficiently severe to cause the combined Scotch and Cambrian glaciers to invade the westerly portion of the Trent basin. I have only been able to show the existence of one period of glaciation during this epoch, but there might have been two or even more, separated by considerable intervals of time. The impossibility of settling this point is due to the lithological similarity which would exist between the several deposits in spite of their different ages.

I have not been successful in finding freshwater shells in the Interglacial River-gravel; but the evidence I shall be able to adduce when that stage comes to be considered in detail, justifies me in regarding them as being due to river-action.

1. *Interglacial River-gravel.*

All the deposits I have described as belonging to the two previous epochs were formed during one continuous period of submergence. No doubt there were considerable oscillations in the depth of this sea from time to time; but no break seems to have occurred during which alluvial gravels and sands were formed until we reach the present stage.

The light thrown upon the contour of the preglacial land-surface by the deposits previously described is of a very scanty nature; indeed nothing of Newer Pliocene age has yet been found. What evidence there is, is furnished by the presence of Older and Middle Pleistocene Boulder-clays at tolerably low levels, at some few points in the vicinity of the present watercourses.

At Sheldon Wharf (fig. 1), a few miles south of Derby, Older Pleistocene Boulder-clay rests upon Keuper marl within 40 or 50 feet from the bottom of the modern valley of the Derwent. North of Swarkestone the Chalky Clay also plunges down to a low level in the valley, which is here that of the Trent. As a general rule, the Boulder-clays of Older or Middle Pleistocene age will be found to occupy lower and lower positions in the valleys the nearer they approach the present watercourses. It would therefore seem that the broader features of hill and valley were sketched out in preglacial times, and that Newer Pleistocene erosion has, after removing the greater portion of the older Boulder-clays from the low-lying areas where they occurred, commenced to widen and deepen the old valleys.

Considering the great thickness of loose sand and gravel which has escaped destruction by the glaciers of the Pleistocene period, it might seem strange that no trace of preglacial river-gravel is now to be found, so far as I am aware, in the Trent basin. For my own part, I am inclined to believe that the Newer Pleistocene erosion, the traces of which are now to be considered, has been so great, and has been carried on so nearly along the lines of the old valleys,

that not only have the Boulder-clays and associated deposits been removed, but the old river-gravels which lay beneath them have shared the same fate.

The Interglacial River-gravel occupies terraces at various heights along the valley of the Trent and its tributaries. I have not traced it in detail out of South Nottinghamshire and South Derbyshire, but no doubt it occurs in equal profusion at other points. The sketch map (fig. 1) shows the distribution of the deposit in sheet 71 S.W.

The long period of submergence brought to a close at the end of the Chalky-gravel stage, by the emergence of the area of the Trent basin above the level of the sea, gave rise to the formation of river-gravels, which at high levels are difficult to separate from the previous marine deposits, owing to the absence of molluscan remains, and also to the disturbance they have suffered by subsequent glaciation.

Unfortunately no freshwater shells have been found in the Interglacial River-gravels; but these gravels present so many characteristics common to river-deposits, and differ so markedly from the Chalky Gravel, that there can, I think, be little doubt about their origin. The main proofs of their interglacial age will be given when the Later Pennine Boulder-clay presents itself for consideration. They generally have a rusty-red, compact appearance, which gives them a look of great age. From their upper surfaces contortions frequently extend downwards, until the rock upon which the gravel rests is bent, broken, or even torn up. Unlike the Chalky Gravel, which forms banks or sloping beds of varying thicknesses, the interglacial alluvium runs for miles in nearly flat terraces of considerable width at almost constant heights above the more modern river-deposits. In many instances the gravel or sand is finely false-bedded in a direction indicating currents down the valleys. A close relationship also subsists between the thicknesses of these deposits and that of the alluvial gravel now being formed by the rivers. It would thus appear that the interglacial rivers were nearly similar in volume and depth to the modern streams; for when the gravels have not been much eroded by Later Pennine ice, the postglacial and interglacial deposits are of similar thicknesses.

In the Dove valley Interglacial River-gravel occasionally overlooks the river from considerable heights.

Near the Yelt Farm, east of Uttoxeter, about eight feet of highly contorted gravel, with flints and beds of sand, forms a terrace at a considerable height above the stream.

Still further to the east, Foston Hall stands on a similar terrace, at a height of 30 feet above the modern plain. The gravel is exposed in two pits, one to the east and the other to the west of the park.

A high-level deposit of rusty-red gravel, with occasional seams of sand, occurs to the east of Hilton. Two sections may be seen—one to the north of the village, and another on the highroad to the east. At this point the thickness exposed is about 10 feet. The whole of the surface-portion is considerably disturbed, the confusion frequently descending several feet.

Another large stretch of similar gravel covers the high land north of Eggington. The railway-cutting east of the station passes through this deposit, and two fine sections are exposed south of the point where the railway crosses the Burton Road.

In the valley of the Trent, and capping or resting upon the southern side of the low range of hills forming the northern escarpment of the river between Findern and Weston, there are long patches of high-level river-gravel, evidently formed by currents running from higher to lower levels down the valley. There are three distinct patches forming, not including breaks, about two miles and three furlongs of terrace reaching a breadth of about three hundred yards. This gravel is the most elevated interglacial deposit of the Trent I am yet cognizant of. It rests at a height above the river considerably in excess of the Older and Middle Pleistocene Boulder-clay at Sheldon and Swarkestone. From this it would appear that when the Trent first began to excavate its Newer Pleistocene valley, it flowed over a considerable thickness of Boulder-clay which had been deposited during the two previous epochs.

The most westerly patch of gravel extends for about half a mile along the hill-top in an easterly direction from Stenson Lock. Two exposures occur, one at each end of the deposit. The most westerly section shows about 15 feet of stratified gravel, with beds of sand. Towards the centre of the section the sand beds reach a considerable thickness, and, by their oblique bedding, indicate currents down the valley. Flints are extremely numerous, occasionally as large as thirty-two pound shot. They were probably derived directly from the Great Chalky Boulder-clay to the west, over which the river was at that time running.

The next portion of this high-level terrace extends for about a mile from Barrow Old Elm to Swarkestone Lowes. At its western end it rests against a small outlier of Chalky Clay, the presence of which was ascertained by boring when mapping this patch of gravel. About the centre of the deposit, on the east side of the road leading from Sinfin Moor, a gravel-pit shows it to be a red stratified gravel with sand beds.

The easterly patch rests upon the sandstone near Weston-on-Trent, and extends from Weston Cliff across the railway for nearly a mile in a north-easterly direction. Two good exposures may be seen—one near the cliff, and another just north of the railway. The height of the upper surface of the gravel is here about 74 feet above the present flood-level of the Trent.

A still lower terrace may be traced from a point a little to the south-east of the church, and through Weston to within about half a mile of Aston. There is a small exposure at the southern extremity, not far from the church, and another to the west of the road at the north end, on the line of section, fig. 3. In both these terraces the steep escarpment which once overlooked the river has been obliterated by the glaciers of the succeeding epoch; but the steep bank and almost horizontal floor against and upon which the gravel rests yet remain.

A still lower series of terraces (similar to those I have noticed in Q. J. G. S. No. 168.

the valley of the Dove) occupy very considerable areas both in the Trent, Derwent, and Soar valleys. These lower terraces of Interglacial River-gravel, or the gravelly moraine of the Later Pennine Boulder-clay stage which has been formed on them, overlook the postglacial deposits of the Trent and other valleys by a tolerably steep escarpment, from 20 to 30 feet high (shown in fig. 3).

South of Burton-on-Trent, between Wichnor and Barton-under-Needwood, a terrace about 50 feet above the alluvial plain of the Trent is covered by highly contorted gravel. At Wichnor a section shows 7 feet of gravel, with red sandy seams resting upon and contorted into Keuper marl. In some parts of the pit large tongues of marl rise in the gravel to a height of 6 feet at least, or are even torn up and mixed with the gravel. The contortions are evidently due to the forcible propulsion of the gravel over the marl. Flints are tolerably numerous. Similar sections may be seen at Barton Green.

A large crescent-shaped terrace of gravel about half a mile broad stretches from Willington to Stenson Lock. The only section is a shallow one to the south-east of the "Dog Inn."

From Willington the escarpment of this terrace runs in an almost unbroken line along the north side of the Trent valley, past Swarkestone, Weston, Aston, and then up the valley of the Derwent past Elvaston, Alvaston, and Osmaston, to Derby.

Between Weston and Aston a still lower patch of gravel than the two higher ones I have previously noticed borders the edge of the escarpment shown in fig. 4; but there is no good exposure.

By far the largest outspread of Interglacial River-gravel stretches along the south-west side of the Derwent valley, south of Derby. Sections are scarce, but in some excavations on the London Road, near the Derby Infirmary, the gravel was met with after passing through seven or eight feet of pebbly morainic clay. The gravel was much disturbed.

Near Alvaston church a gravel-pit on the edge of the escarpment shows a rather poor section of reddish gravel with an occasional bed of sand. The pebbles are quartz and quartzite, flint and chert.

On the north-east side of the valley of the Derwent gravel of similar age and appearance also spreads out in extensive terraces.

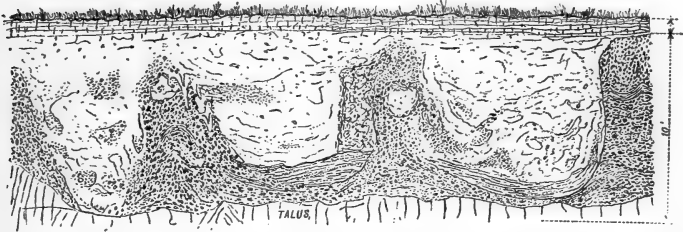
A small patch occurs near Borrowash station. Here the railway-cutting has been excavated through the feather edge of the gravel capping the escarpment. Not far from the station an exposure may be seen in a gravel-pit on the roadside.

A much larger patch of Interglacial River-gravel extends, with a breadth exceeding half a mile, from Draycott past Breaston to within half a mile of Long Eaton. On the river-side it is bounded by a steep continuous escarpment of considerable height. Only one rather poor exposure of the gravel is to be seen in a pit to the east of Breaston.

Between Trent and Nottingham the only patch of this gravel which has escaped destruction by postglacial erosion lies on the hill-side at Beeston. Several good sections may be seen. The deposit has been well described by Mr. Shipman in a paper read before the

Nottingham Naturalists' Society in 1879. He says:—"It is best seen, however, in a large ballast-pit, off Stony Street, Beeston, where it consists of well-rounded pebbles interbedded with thin seams and

Fig. 4.—*Contorted Interglacial River-gravel, Gamston, near Nottingham.*



broad irregular bands of dull brown sand. The bedding is mostly horizontal; but in some parts, where the sand beds are interwedged with the gravel, they slope (and are current-bedded) towards the south-east, indicating that the water which brought the sandy sediment came from the north-west. The pebbles are chiefly quartz and quartzites, but there are besides pebbles and boulders of Coal-measure sandstone, chert, Lower and Upper Keuper, while about 10 per cent. are flint chips, with a few perfect flints. The drift, which is here from twelve to fourteen feet thick, is seen resting on a level floor of Bunter pebble-beds. The section in the gravel-pit shows signs of having been disturbed by some force acting laterally in such a way that in some parts where the gravel is bedded the alternations of sand and gravel have been squeezed into folds and sharp convolutions." The deposit is about a quarter of a mile in width, and extends from Chilwell as far as Tottle Brook, along the north-west side of the highroad.

Another large crescent-shaped patch of gravel occurs at Gamston, south-east of Nottingham. This deposit extends from a point a little to the west of the canal, in an easterly direction about half a mile beyond the "Fox and Crown." It is breached by a small brook near Gamston, and also by the Thurbeck river. Two sections may be seen—one in the village of Gamston (fig. 4), where the gravel is highly contorted, and another west of the "Fox and Crown."

2. *Later Pennine Boulder-clay.*

The mild climatic conditions which for such a considerable period obtained during the deposition of the Interglacial River-gravel again gave place to an arctic climate, and glaciers once more formed in the higher valleys and advanced to considerable distances over the surrounding lowlands. From the widespread distribution of the Boulder-clays thus formed, and the distant erratic boulders they contain, this stage must have been one of confluent glaciers and great cold.

Though I have named it the Later Pennine Boulder-clay stage, it must not be supposed that Pennine rocks always form a large percentage of the deposit; indeed it is frequently almost wholly formed from the subjacent rocks, with the addition of a few Pennine, Cambrian, or even Cumbrian erratic boulders. My reason for calling it Later Pennine is more to mark the return of local ice-action, interrupted during the Middle Pleistocene epoch by the formation of the Great Chalky Boulder-clay, than to indicate its lithological characteristics.

The deposits formed during the Later Pennine Boulder-clay stage resemble those of Older and Middle Pleistocene times in having been formed by ice which came from the same quarter, but they differ from them in many other most important respects. The Older Pleistocene Boulder-clays are partly sedimentary, while these later deposits are almost entirely unstratified, and when pebbles or boulders occur, a fair percentage of them are of flint. During the Middle Pleistocene epoch Cretaceous rocks were not carried many miles up the northerly tributaries of the Trent, so that in these valleys this test for age is not always available.

Whenever the rocks upon which the Boulder-clay rests are exposed they are seen to be more or less contorted. Sometimes this crushing has not been sufficient to entirely obliterate their stratification and convert the rock into a morainic Boulder-clay. These signs of disturbance in many cases become so great as they are traced horizontally, that the rock passes into true moraine; and when this is so, the Boulder-clay passes into contortions both horizontally and vertically. It is therefore evident that the contortions seen in the surface-portions of so many sections are of the same age as the Later Pennine Boulder-clay, and were formed by the same ice-sheet.

Unlike the earlier deposits, these subglacial moraines are strictly conformable to the major features produced by the previous interglacial erosion, and in this respect offer a marked contrast to the preceding formations, which may be described as generally conformable to the preglacial land-surface, and to have had the more modern valleys, in which the Later Pennine Boulder-clay occurs, excavated through them.

In many cases it is scarcely correct to call this moraine a Boulder-clay; for it is occasionally quite free from clay, consisting of gravel and sand so disturbed that all traces of original stratification, if they ever existed, have been destroyed.

All the Boulder-clays and gravels from the Early Pennine down to the Interglacial River-gravel have been crushed at the surface or even partially converted into newer Boulder-clay. Flints have by this means been introduced to considerable depths into the surface-portions of non-flinty deposits. It is therefore never safe to say that that rock is present in a Boulder-clay when found near the surface, until it has been positively ascertained that the section shows no traces of disturbance by Middle or Newer Pleistocene ice.

In addition to the evidence furnished by the presence of erratics, the direction in which the ice-sheet moved is indicated by the trend

of the furrows and ridges of the contortions, or the direction in which the underlying rock has been trailed.

The Later Pennine Boulder-clay and contortions of the same age are scattered over the greater part of the Trent basin, and attain their greatest development in the interglacial valleys, or on the more elevated plateau-like areas. In postglacial times the clay was carried away from large districts by river-action, or denuded from the steeper slopes by ordinary atmospheric influences; it is now found where the land is tolerably flat, and might be passed over in the absence of boulders, or when the rocks beneath it are tolerably uniform in character or show no very evident traces of bedding. The absence of pebbly or sandy beds in the neighbourhood immediately to the north or west also contributes much to this result.

Many geologists express themselves very doubtful as to whether ice-action has really in any way contributed to the formation of the contortions and masses of unstratified pebbly clay, preferring to attribute their existence to a slow soil-cap motion or the disturbing action of roots. No doubt the feeling arises from a knowledge that it is always unsafe to attribute the existence of any phenomenon to the action of an agency which is little understood. I have kept this well in view, but after a careful examination of many hundreds of sections, I see no reason whatever to doubt the glacial origin of the contortions and stony clays.

Of the reasons which have led me to this view, the following are among the more important:—

1st. The trend of the ridges and furrows of the contortions seldom shows any dependence whatever upon the direction of the slope. In many instances the action has been down the valley at right angles to the slope of its sides.

2nd. In some cases a movement up the slope is indicated.

3rd. The contortions are equally well developed on flat areas.

4th. On the steeper slopes formed by postglacial erosion contortions are quite absent, the only effect of the angle and exposure being to slightly dip the beds towards the valley.

5th. When the contorting force has faulted gravels, the quartz, quartzite, and flint pebbles along the line of disturbance are frequently fractured, the fragments remaining in close juxtaposition.

6th. The displacement and breaking up of massive rock-beds also points to the action of a powerful agency.

7th. The contortions are exactly similar to those beneath the older Boulder-clays.

8th. The direction of the ice-flow, as indicated by the trend of the ridges and furrows, is corroborated by the origin of the included erratics.

9th. Well-striated erratic boulders sometimes occur in the surface Boulder-clays.

10th. All traces of contortion are absent from postglacial river-gravels, even where they occupy terraces as much as fifteen feet above the valley-bottoms, the terrace shown in fig. 3 always separating the newer from the older contorted gravels.

11th. The present atmospheric agencies are not forming, but are destroying such deposits.

12th. The major axes of the pebbles frequently coincide with the trend of the furrows and ridges.

All these physical peculiarities point to ice, glacier ice, as the agency to which they owe their existence. In some few cases the contortions appear to have been formed by the névé which collected on the hills before the cold conditions finally passed away.

As mentioned before, there is nothing to prove that the deposits I shall describe in this stage might not have been formed during more than one interval of cold occurring while the deposition of the Inter-glacial River-gravels took place. If such had been the case the morainic clays thus formed at different periods would be too much alike, both as regards lithological character and mode of occurrence, to be now distinguishable the one from the other.

That such a widespread deposit should be generally so thin, and that the ice which formed it should have accomplished such a moderate amount of work, judging by the deposits it has left behind it, as compared with some of the earlier glaciers, will perhaps be urged against my contention that this was a period of great cold and confluent glaciers. Its comparative thinness may be accounted for by the fact that, where I have seen it in the Trent basin, the deposit is either wholly subglacial or subaerial. Some geologists have even gone so far as to argue that no deposits whatever of Boulder-clay are ever formed beneath ice-sheets, their action being considered entirely erosive. On the other hand, others have adopted an equally extreme view both as regards their aqueous and subglacial origin. The truth probably lies somewhere between these extremes, and it may be that instead of the subglacial moraine being entirely mythical, it more frequently occurs as a moderately thin Boulder-clay similar to the one now to be dealt with.

In Staffordshire the Later Pennine Boulder-clay contains Pennine, Cumbrian, and even Cambrian erratics; while in Nottinghamshire and Derbyshire the boulders are almost wholly either of Pennine or local origin. South of these counties it is generally more scantily developed. I shall therefore first notice its mode of occurrence in Staffordshire, then trace it through Derbyshire and Nottinghamshire and finally south into Leicestershire.

Mr. D. Mackintosh describes several Staffordshire sections of Boulder-clay. At one time he was inclined to believe that they belonged to a later stage than the Chalky Clay; but in a recent paper they are regarded as its westerly continuation. For many reasons I am inclined to believe that his early view was the more correct.

In Wolverhampton itself there are several exposures. In these sections the deposit, which is of no great thickness, consists of local rock, very much broken and disturbed, together with pebbles and boulders of distant origin.

West of the Cemetery it is worked to a depth of five or six feet. Here and there it contains intruded masses of sand, and, in addition

to pebbles and boulders of local rock, flints and granite. In the Cemetery itself an excavation passed through reddish Boulder-clay containing masses of sand with shell-fragments. In an old pit close by the Boulder-clay rests upon shelly sand over which it has been forcibly thrust.

Where the Chalky Gravel rests upon, or has been formed in the immediate vicinity of, Chalky Clay, it contains numerous large boulders derived from that deposit. In Staffordshire they are much more scarce in the Chalky Gravel, the erratics mentioned by Mr. Mackintosh belonging, almost without exception, to the Later Pennine Boulder-clay. With regard to this point the Rev. W. S. Symonds remarks*, "I have observed one peculiarity as regards this sand and gravel and fossiliferous drifts in several localities, as near Wolverhampton, near Shrewsbury, and in Yorkshire: it is that they often have large boulders lying immediately above them, or on their upper surface, as if the boulder erratics had been deposited after the accumulation of the shell-bearing sands and gravels." This statement describes their general mode of occurrence, the Chalky Gravel with its boulders and pebbles having been formed by the marine denudation of the Chalky Clay, and the Later Pennine Boulder-clay, with its large erratics, by the glaciers which entered the Trent basin from the surrounding mountainous districts to the north and west.

South of Penkridge about five feet of highly contorted sandy Boulder-clay rests upon disturbed red marl. Boulders are numerous, many of them of rocks entirely foreign to the district.

A stone-quarry near Brewood Farm, excavated in Keuper sandstone, which here contains footprints of *Labyrinthodon*, shows the upper five or six feet of red marl mixed with pebbles and sand and converted into a morainic clay.

Not far from Penkridge another interesting exposure may be seen. Pebbly sand or clay, three or four feet thick, here covers red marl, which in its turn rests upon beds of massive fine-grained sandstone. Below the red marl the sandstone layers are violently disturbed and broken, the red marl being thrust into the crevices between the displaced blocks. It is evident from the section that the disturbing force passed over a surface whose contour corresponded very nearly with the present one, the modern streams having only excavated shallow valleys through the old glaciated surface.

Between Penkridge and Stafford the only exposure I am aware of is the one at Ash Flat, mentioned by Mr. Mackintosh. The section shows about seven feet of reddish Boulder-clay. I was informed that for three or four feet beneath the usual working-depth it is more stony and rests upon sand—probably Chalky Gravel—from which the water rises in powerful springs. The clay contains intruded masses of sand, and besides pebbles of quartz, quartzite, sandstone, &c., a few flints may be found.

All these sections, occurring as they do immediately to the west of the South-Staffordshire Coal-field, should contain, if they belong

* 'Records of the Rocks.'

to the Great Chalky Boulder-clay stage, a fair percentage of Carboniferous rock-débris; not only is this not the case, but northerly and westerly rocks predominate. Indeed the direction of the ice-flow which formed this Boulder-clay was what we should expect from the distribution of the present British hills, and not from a flow from the east or north-east such as gave rise to the Great Chalky Boulder-clay. The flints were derived from the gravel of the previous stage. Among the distant erratics Mr. Mackintosh has detected felstone from Mount Arenig in North Wales, granite from Criffel in Scotland, and granite from Esk Dale in Cumberland.

North of Stafford, near the Marl-Pit House, a pit in the Keuper exposes a layer of reddish Boulder-clay with quartz pebbles and flint. In some cases the gravelly masses have been thrust into the marl to a depth of seven feet.

At Walton Heath, near Stone, an excavation shows ten feet of red morainic Boulder-clay with quartz, quartzite, gritstone, sandstone, and an occasional flint.

About four miles north-east by east of Stone, in a brick-yard near the "Bird in Hand," Older Pleistocene Boulder-clay is covered by about ten feet of red gravelly Boulder-clay with flint.

In East Staffordshire the Later Pennine Boulder-clay may be seen in many sections; but the Cambrian and Scotch erratics so plentifully spread over the west of the country are replaced by Carboniferous boulders from the Pennine Hills. Along the river-escarpments the Boulder-clay is generally a deposit formed by the destruction of old river-gravels, or, on the higher lands, by the breaking up of Chalky Gravel.

North-west of Uttoxeter a pit exposes nine or ten feet of gravelly moraine, quite unstratified. The pebbles stand at all angles in a matrix of red marl. Flints are tolerably plentiful. The boulders, though generally well rounded, are sometimes quite angular.

South of Uttoxeter, and in the neighbourhood of Abbots Bromley, many exposures show the Chalky Gravel either partially or wholly converted into Boulder-clay.

The high-level terrace overlooking the Trent near Wichnor, at a height of about fifty feet above the river, is capped by about seven feet of disturbed gravel. In some places the disturbance is so great that the Keuper marl rises in pointed masses into the gravel to a height of at least six feet. Sometimes the masses of red marl appear to have been quite detached from the rock below and imbedded in the gravel. The deposit extends as far as Barton Green, where good sections may also be seen. As the disturbed gravel is here almost perfectly horizontal, the contortions could not have been formed by soil-cap motion.

South of Tutbury, near where the road crosses a brook, half a mile from Belmott Green, boulders of Mountain Limestone are imbedded a few feet deep in the marl. There is a similar but much larger accumulation of erratic boulders in Mr. Hodge's brick-yard, near Burton-on-Trent. This pit has been opened out on the side of a small lateral valley of the Trent formed in interglacial times.

Though the sides of the valley slope with a tolerably steep incline, its bottom, with the exception of a V-shaped "dumble," about 15 feet deep, due to postglacial erosion, is rounded. The lower portion of the excavation, where it cuts into the hill about ten or fifteen feet above the bottom of the old valley, enters a morainic deposit of Boulder-clay which clothes the side of the hill to a height of about fifty feet. In its thickest part it attains a depth of about six feet. It contains boulders of Mountain Limestone, basalt, sandstone, &c. Sometimes it is a mere rubble of limestone chips with quartz-pebbles and an occasional flint. One limestone boulder measured $5' \times 3' \times 3'$; and another, nearly as large, was finely grooved and scratched on one face. Many of the boulders occur scattered over the face of the section from two to three feet deep in clean marl. At many other points in the neighbourhood of Burton-on-Trent, both in Staffordshire and Derbyshire, boulders of Pennine rock either lie on the surface or are imbedded in the marl a few feet from the surface.

In South Derbyshire and Nottinghamshire the Later Pennine Boulder-clay is also well developed.

One mile N.N.W. of Sudbury, near Oak Green, about 9 feet of red gravel with sand-beds has been greatly disturbed. It contains pebbles of flint, quartz, quartzite, chert, toadstone, and gritstone.

In addition to the more or less contorted Interglacial River-gravels (fig. 4) which have been described as belonging to a previous period, there are gravels and sands like those on the "Hill Top," near Ashbourne, and at Oak Green, which, though originally aqueous deposits, have been converted into Boulder-clay. It is difficult in many instances to be certain whether many of these deposits were originally of marine or fluvial origin; they are now Boulder-clays or, more properly speaking, Boulder-sands.

High-level Boulder-clay is exposed in a shallow excavation at Heath House Green, north of Tutbury, and again on the road southwest of Sutton-on-the-Hill.

North-west of Derby, along the course of the Markeaton brook, there extends a long patch of gravel, probably washed down from the Bunter Conglomerate and converted by Later Pennine ice into unstratified moraine. North of Markeaton, on the west side of the brook, there is a good exposure; it is here an indurated, coarse, red, sandy gravel, exhibiting little sign of original stratification, but containing a few lenticular beds of sand. A few flints and angular pieces of Keuper sandstone occur; but the mass of the gravel consists of quartz and quartzite pebbles. Another exposure, about 11 feet deep, of the same deposit, may be seen near the Ashbourne road, just before leaving Derby; the same almost entire absence of sand-beds is here shown. Not far off, near Stretton's Brewery, a deep excavation passes through Boulder-clay of the same age, and probably continuous with this disturbed gravel. The moraine is here at least 10 feet thick, and consists of pebbles stuck at all angles in Keuper marl. The Boulder-clay stretches, with a thickness sometimes exceeding 10 feet, over the greater part of the northern and eastern

slopes of Mill Hill, and also over the interglacial alluvium on the south-west side of Derby. Many good exposures have been opened out in excavating for cellars. On the Normanton road, at the top of Hartington Street, a very good section was shown. About 9 feet of Boulder-clay, consisting of red marl, with sand, large flints, and pebbles, rested upon a violently contorted bed of sand in the Keuper. The Boulder-clay had evidently been thrust over the sand by a force acting from the west and north.

Contorted sandy Boulder-clay, with great numbers of flints and occasional large boulders of Carboniferous Limestone, gritstone, &c., caps the western escarpment of the Derwent where it overlooks Little Chester.

Along the north side of the Derwent, from Borrowash to Long Eaton, the same gravelly Boulder-clay is extensively spread out. In addition to several sections at Borrowash and Draycott, a good exposure may be seen in a brick-yard near Wilsthorp Cottage, south-east of Risley.

In the Erewash valley, at Stanton Gate, the Later Pennine Boulder-clay, which is exposed in a brick-yard, has been formed by the breaking up of the clays of the Coal-measure period. Similar Boulder-clay was shown in an excavation on the road leading from the station to Ilkeston. At this spot a thin seam of coal had been trailed in a direction, as near as could be made out, down the valley.

In the Leen valley, near Nottingham, the Boulder-clay, according to Mr. Shipman, reaches a thickness varying from 2 to 6 feet. The deposit was well exposed in sinking wells for new gasholders. At Radford the modern alluvium of the Leen occupies a wide trench cut through the Boulder-clay. Here it is a stiff sandy clay thickly studded with pebbles; no regular bedding is visible, the pebbles lying in the clayey matrix at all angles.

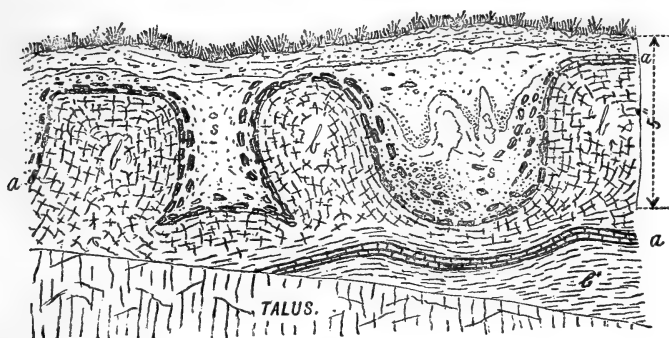
Speaking of the distribution of the Boulder-clay, and after referring to the existence of older deposits, Mr. Shipman says*, "It was during the last of these periods of glaciation that the red loamy and pebbly sand seen along the foot of the south wall of Wollaton Park, and, indeed, the whole of the drift of the parish of Lenton, appears to have been deposited. It bears evidence of having been derived from the grinding down of the rocks by the passage of ice as it descended from the Pennine Hills across the country in a south-easterly direction; for the chief ingredients of the deposit are invariably such as could only have come from the north or north-west, mixed up with materials derived from the grinding down of the rocks on which the deposits rest. Four or five miles further west, in the neighbourhood of Stanton Gate, beyond the Erewash, drift-deposits of this age assume considerable importance, and betray all the usual signs of ice-action, such as highly disturbed bedding, in which strata have been crumpled and puckered and the pebbles squeezed into a highly inclined or vertical position by the action of lateral pressure; while in other spots the drift consists of a heterogeneous mixture of

* 'Geology of the Parish of Lenton.'

pounded rock-fragments torn up by the advancing ice-sheet, and crushed and kneaded into a stiff lumpy clay."

Near Radcliff, on the Bingham road, there was some years ago an excellent section exposing a highly contorted bed of sandstone in the Keuper. The upper sandy clay and sandstone (fig. 5) had been

Fig. 5.—*Contorted Keuper Marl and Sandstone, Radcliff, near Nottingham.*



a a. Sandstone beds; *b.* Disturbed Blue Marls; *s.* Sandy clay with angular pieces of sandstone &c.; *b'.* Red Marl.

removed by the pitmen from a considerable tract, leaving exposed a ridged and furrowed surface indicating roughly a flow from about the west.

Similar deposits may be seen at many points in the Soar valley and its tributaries.

South of Kegworth Station and east of the highroad there is a section showing gravel with flints contorted to a depth of 4 feet into the marl.

South of West Leake, at Gorse Cover, and in clay-pits at Humberston, Barkby, Rearsby, Thurmaston, Barrow, &c., there are similar exposures.

Boulders of Charnwood rock are scattered over the Keuper rocks to the north of the Charnwood Hills, and at one point the railway passes through a cutting in a moraine evidently formed by local Charnwood glaciers moving in a northerly direction. The section referred to is to the east of Thringston. Here it is a Boulder-clay, consisting of angular or rounded masses of Palæozoic rock from the south, stuck at all angles in a matrix of Keuper marl. The moraine is about 12 feet thick, and contains here and there little nests or beds of sand or pebbles with an occasional flint; otherwise it shows no trace of aqueous action.

DISCUSSION.

The PRESIDENT said that glacial sections in Eastern and Western Britain had been much discussed, and consequently Mr. Deeley's

work in the Midland districts was a most useful contribution towards the correlation of the Drift-deposits of the British Islands.

Prof. BLAKE congratulated the Author on the amount of work he had done. He remarked on the difficulty of determining the duration of glacial flows. The Drift about Nottingham is very peculiar and exhibits many varieties; one form contains igneous rocks largely, probably from Derbyshire and the west. Beneath are false-bedded sandy beds; above comes the Chalky Boulder-clay with eastern rocks, Chalk, Oolite, and Lias, besides the volcanic rocks, which may be *remanié*. Another bed is formed entirely of Carboniferous Limestone, beautifully striated. Besides these beds there are the well-stratified coarse gravels. He had himself never been able to understand the whole sequence.

Rev. A. IRVING inquired about the great range of Boulder-clay south of Nottingham, where it is 70 feet thick, overlying Lias shales. This Boulder-clay contained Charnwood-Forest rocks, and occasionally Carboniferous Limestone, but was mainly reconstructed Lias.

Dr. HINDE pointed out that the distinctions between the different Boulder-clays were unmistakable. He inquired about the evidence of marine submergence, and noticed that in Bavaria immense fresh-water beds, gravels of great thickness, had been formed in connexion with glaciers.

Mr. TEALL was imperfectly acquainted with the district, but could testify to the large amount of careful work done by Mr. Deeley. The appearance of the deposits was at first sight most perplexing, but Mr. Deeley really appeared to have succeeded in establishing a definite sequence.

The AUTHOR said that his results were not dissimilar to Prof. Blake's, all of whose remarks supported the views mentioned in the paper. He explained the dispersion of the Charnwood-Forest rocks alluded to by Mr. Irving. The distribution of the Quartzose Sand could only be explained by assigning to it a marine origin. Mollusca only appear in the Chalky Gravel along the westerly watershed of the Trent basin in Staffordshire and Cheshire.

38. *On some DERIVED FRAGMENTS in the LONGMYND and NEWER ARCHÆAN ROCKS of SHROPSHIRE.* By CHARLES CALLAWAY, Esq., D.Sc., F.G.S. (Read June 23, 1886.)

IN my papers on the Archæan rocks of Shropshire I have touched upon the evidence of age furnished by included fragments. I stated* that the Longmynd conglomerates of Haughmond Hill contained pebbles of purple rhyolite similar to the typical rhyolites (Uriconian) of the Wrekin. In the Uriconian † series itself I had found conglomerates ‡ full of rounded pieces of granitoid and gneissic rocks, evidently derived from a crystalline area of which Primrose Hill, at the south-western end of the Wrekin, was an undenuded fragment. I have since been able to enlarge this evidence, and, in order to give precision to previous conclusions, a series of specimens have been submitted to microscopic tests.

The Longmynd Rocks of Shropshire largely derived from the Uriconian Series (Newer Archæan).

The plum-coloured conglomerates and grits of the Longmynd hills are well known. With the exception of a band of pale-green slate fringing the area along its eastern margin, they form the chief mass of the formation. Whatever estimate of their thickness may ultimately be obtained, there is no doubt that these sediments represent the washings from a very considerable extent of land.

The conglomerates are sometimes crowded with pebbles of purple rhyolites absolutely undistinguishable under the microscope from well-known Wrekin types, and many of the fragments display the spherulitic and perlitic structures originally described by Mr. Allport §. Well-rounded pieces of a pale-green felsite are less common.

The prevailing grits are of a purple colour. Quartz is the most abundant constituent; the purple rhyolite comes next. Fragments of felspar and mica are also seen, and, occasionally, bits of mica-schist. The proportions of these constituents vary with the locality. South of Church Stretton the grits contain a large admixture of materials derived from a granitoid district. In Haughmond Hill, at the northern end of the Longmynd mass, there is a green grit (No. 209, *infra*), which would seem to have originated from the denudation of a region of mica-schist; but within a hundred yards is an outcrop of conglomerate packed full of rhyolite pebbles.

One of the typical green slates (No. 211) has also been microscopically examined. The rock is apparently of mixed origin; it contains minute fragments of quartz and mica; but Prof. Bonney, who has been kind enough to look through my slides, writes:—"It

* Quart. Journ. Geol. Soc. 1879, vol. xxxv. p. 661.

† These rocks may be Pebidian, but, in the absence of positive proof, a local term is convenient.

‡ Quart. Journ. Geol. Soc. 1879, vol. xxxv. p. 654.

§ Ibid. 1877, vol. xxxiii. p. 449.

is very probable, as you suggest, that the materials" (of this slate) "may have been partly derived from old rhyolites."

The following is a condensed description of a series of slides cut from typical varieties of rocks of the Longmynd series, usually regarded as Lower Cambrian, and certainly not younger. The quotations are from notes furnished by Prof. Bonney:—

201. Pebble of conglomerate at Oak's Hill, near the western margin of the Longmynd area. Purple rhyolite, "devitrified, fluidal structure well shown."

202. Pebble from the conglomerate at the summit of the Longmynd, S.E. of Ratlinghope. Devitrified rhyolite, crowded with spherulites, "traces of perlitic structure (anterior to devitrification) exhibited here and there in the interspaces of the groups of spherulites."

203. Pebble from conglomerate, Haughmond Hill, N.E. of Shrewsbury. Occurring in association with a great majority of pebbles of the purple rhyolite. Pale-green compact felsite. Regarded as probably a "devitrified obsidian."

204. Pebble from same conglomerate as No. 202. Pale-green quartz-felsite, with perlitic structure. Prof. Bonney notices "indications of flow-brecciation."

205. Coarse purple grit above great conglomerate, Haughmond Hill. Composed of bits of quartz, purple rhyolite, mica-schist, and felspar. "Full of fragments of volcanic materials, many of them bits of scoria," the majority of the fragments belonging to the "acid series of volcanic rocks."

206. Purple grit, Aston-on-Clun. Mostly quartz, but a few bits of felspar and of rhyolite. Largely derived from granitoid rocks. "One fragment resembles a chip of mica-schist."

207. Very typical plum-coloured grit from the head of Cardingmill Glen, west of Church Stretton. "Volcanic materials of the usual type abundant." Prof. Bonney also agrees with me that bits of mica-schist are probably present. I may add that I have found pebbles of mica-schist in the overlying conglomerates.

208. Speckled grit, West of Hopesay Common. Composed of quartz, felspar, and a small proportion of volcanic fragments.

209. Pale-green grit, Haughmond Hill. Bits of quartz and felspar, with mica and a small proportion of felsite. "Suggests partial derivation from a mica-schist."

211. Typical pale-green slate, Haughmond Hill. Noticed above (p. 481).

It may be safely concluded that, during the deposition of the Longmynd series, the adjacent lands were largely composed of purple rhyolites, pale-green felsites and quartz-felsites, granitoid or gneissic rocks, and mica-schists. The Archæan age of the Wrekin volcanic series, to say nothing of the metamorphic rocks, thus receives ample confirmation. As the strike of the Uriconian is almost uniformly east and west, while the strike of the Longmynd rocks is steadily to the S.S.W., there would appear to be a considerable break between the Archæan and Longmynd periods.

The Uriconian Series partly derived from pre-existing rock-groups.

Conglomeratic beds containing rounded fragments of granitoid rock are found in the very core of the Wrekin axis, for example, in the large quarry at Lawrence Hill; but the conglomerates of Charlton Hill furnish a great variety of well-worn pebbles of pre-existing rocks, chiefly metamorphic. It will be well, in this place, to review the evidence for the Archæan age of these interesting strata.

On the top of Charlton Hill the conglomerate appears in several small outcrops which lie approximately in a line running east and west; but no clear bedding is visible at this spot. A few feet to the north, we find ordinary gritty and slaty rocks of the Wrekin series, and in the adjoining field and lane there are numerous exposures of typical volcanic grit. A few yards to the east of the conglomerate ordinary Wrekin rock also occurs; but the decisive section is in the hollow lane to the south. In the northern bank is a well-marked band of pebbly grit, with a clear dip to the north at 80°. This is the usual dip of the Uriconian series as regards direction, but the angle is exceptionally high. The contained fragments (No. 200, *infra*) of this bed are similar to those in the chief conglomerate, but smaller. The ordinary volcanic rocks overlie and underlie, and a little lower down the road the underlying beds are overlain in a very clear section by quartzite, dipping south-easterly at about 50°. The rocks between the grit and the quartzite are exposed in unbroken series, so that evidence of unconformity between the two groups is complete. The relations between these volcanic rocks and the quartzite are the same as at the Wrekin, and as the former are lithologically similar to the ordinary Wrekin grits and dip in the same direction, there is no reasonable doubt that the Charlton conglomerates are of Uriconian age.

The following descriptions are of slides from the chief conglomerate at the top of the hill, except No. 200, which is from the pebbly grit in the hollow lane. Fragments of rhyolite are found in all the specimens; but as these result from contemporaneous denudation, they will not be further noticed. Most of the pebbles show very clear rounded outlines under the microscope:—

195. Fragments of granitoidite, quartz-schist, and a crystalline rock consisting of decomposed felspar, quartz, and chloritic minerals.

196. Granitoid rock, quartzite, and vein quartz. Prof. Bonney considers that the fragments of the first-named variety have “undergone crushing and been recemented with secondary quartz previous to their conversion into pebbles.”

197. In addition to some of the above varieties, this slide contains an angular fragment of argillite and one of grit, composed of bits of quartz and quartzite in a matrix of micaceous material. This grit strongly suggests the “mineralized grit,” which I described in my paper on Donegal* as characteristic of the Lough-Foyle series.

198. Fragments of the altered grit, quartzite, quartz-schist, and

* Quart. Journ. Geol. Soc. 1885, vol. xli. p. 231.

gneissoid rocks. Prof. Bonney considers that one of the last-named varieties "almost certainly exhibits a gneissoid structure due to crushing and cementation anterior to the making of the pebble."

199. Some of the above kinds, with mica-schist and a banded gneiss. In this slide, as in one or two of the preceding, is a rock consisting of a little quartz, some decomposed felspar, and a large proportion of a chloritic mineral. It reminds me of some altered diorites I have seen; but Prof. Bonney declines to decide whether it is igneous or metamorphic.

200. Pebbly grit, containing fragments of the altered grit, quartz-schist, and mica-schist, as before.

These specimens point to the pre-existence of metamorphic rocks of three types:—

(1) Coarse-grained gneissic and granitoid rocks like those in the Wrekin chain, at the Ercal and Primrose Hill, and in the Malvern Hills.

(2) Quartzites, quartz-schists, and mica-schists of characters intermediate between (1) and (3)—that is to say, of finer grain and, in the case of the schists, of clearer foliation than (1)—but exhibiting no trace of an original clastic structure. Comparing them with rocks with which I am personally acquainted, I find they most closely resemble some of the schists of the Kilmacrenan series * in Donegal, and certain types which I have recently examined in Connemara.

(3) Hypometamorphic grit. The clastic structure in this rock is quite distinct; but the matrix has been more or less altered into crystalline minerals. Omitting cases of contact metamorphism, I do not know of any rocks of this kind except amongst the newer Archæan series of Anglesey, the Lough-Foyle group, and some of the Archæan rocks near Wexford. I have also detected at Westport, co. Mayo, altered grits which suggest this rock.

The occurrence of rounded fragments of this grit in the Charlton-Hill conglomerate cannot be a case of contemporaneous denudation, since, on every probable theory of metamorphism known to us, the alteration could not have been produced at the surface. That the change took place subsequent to the inclusion of the pebbles in the conglomerate is improbable, for the matrix of the conglomerate itself does not display mineralization. The presence of this grit in an Archæan conglomerate is a datum of great interest.

The bearing of the above facts upon the Archæan controversy is obvious. In the Shropshire area, in times anterior to the Cambrian, there existed, in addition to the volcanic series, three groups of rocks displaying a close lithological resemblance respectively to (1) the Hebridean and Malvernian gneisses; (2) the intermediate schists of Ireland, Sutherland, and Anglesey; and (3) the hypometamorphic grits of Anglesey and Ireland. All of these Salopian rocks had undergone more or less metamorphism prior to the outburst of the later Archæan volcanoes. The Charlton-Hill con-

* Quart. Journ. Geol. Soc. vol. xli. p. 230.

glomerate does not indeed prove that all the altered rocks of Ireland and the Highlands are Archæan ; but the evidence it furnishes deserves consideration.

It will be seen from the following note, which the writer kindly permits me to publish, that Prof. Bonney is in substantial accord with my identification of the fragments in the conglomerate and with the inferences based upon them :—

“ Your slides confirm the anticipation raised by my own specimens of the Charlton conglomerate, that it would be found to contain fragments of schists of a newer type than we might expect to find among the typical Malvernian rocks. Coarse granitoid rocks, sometimes consisting mainly of quartz and felspar, sometimes containing a fair amount of green minerals probably replacing hornblende or augite, are common. These may in some cases be true igneous rocks, but others exhibit structures allied to the gneisses—in short, they offer the same difficulties that we generally find among the rocks which, when we can settle their stratigraphical position, we know to be of great antiquity. The fragments are such as we should expect to obtain from rocks similar to those exposed at either end of the Wrekin and in the Malvern chain. But besides these there are schists, quartzose and micaceous, which remind me of those which occur at higher horizons in Scotland and in Anglesey, and in the uppermost group of the true schists in the Alps. In addition to these we have quartzites and grits, exhibiting a certain amount of metamorphism, also an argillite, and varieties of rhyolitic rocks, suggestive of a volcanic origin.”

DISCUSSION.

The PRESIDENT remarked on the difficulty, as a general rule, of identifying pebbles in a conglomerate bed, though there are doubtless some rocks of such striking characteristics that identifications of this kind may be made with a high degree of probability.

Professor HUGHES quite agreed with the Author that there was abundant evidence from the masses of Archæan now seen in that district that the rocks exposed there in Pre-Cambrian times consisted of granitoid rocks, felstones, and various schists. He had himself found pebbles of granitoid rock in the conglomerate of Charlton Hill ; but he thought that the Charlton-Hill conglomerate was the base of the Cambrian, and could not understand the Author's argument if he called it Archæan.

Prof. BONNEY said that the most characteristic varieties of the Lea rock had not been and were not likely to be found, but rocks similar to the devitrified pitchstones of the district were abundant. He was under the impression that the Charlton-Hill conglomerate was Pre-Cambrian, at least that it was older than the quartzite, and was not immediately connected with the volcanic rocks of the Wrekin. The speaker explained Dr. Callaway's views, and showed the resemblance of the fragments found in the Charlton-Hill conglomerates to rocks occurring in the Malvern series and some of the Archæan rocks occurring in the Alps and elsewhere.

39. NOTES on the RELATIONS of the LINCOLNSHIRE CARSTONE. By AUBREY STRAHAN, Esq., M.A., F.G.S., H.M. Geological Survey. (Read June 23, 1886.)

(Communicated by permission of the Director-General.)

THE Carstone of Lincolnshire lies immediately below the Red Chalk, and rests upon the fossiliferous clays and limestone known as the Tealby Beds. The Tealby Beds were described in detail for the first time in 1867* by Professor Judd; and their relations to the Speeton section, and to beds of the same age throughout Northern Europe, were discussed in 1870† by the same observer. In 1883 the survey of the district was completed, with the result of verifying in almost every particular the conclusions which had been so ably worked out by Professor Judd. On one point only I ventured to form a somewhat different opinion, namely on the relations of the Carstone to the Red Chalk above and to the Tealby Beds below.

The following table gives (in brief) the correlations advocated by Prof. Judd, and shows also the names of the various subdivisions which have been adopted for the Survey publications, and which will be used in this paper:—

	Judd. Yorkshire.	Judd. Lincolnshire.	Survey Nomenclature. Lincolnshire.
Gault	Hunstanton red rock.	Hunstanton red rock.	Red Chalk.
	Unconformity.		
Upper Neocomian }	Speeton Clay. {	Upper Sands	Carstone.
Middle Neocomian }		Tealby Series.	Tealby Beds. {
Lower Neocomian }		Lower Sands and Sandstone?		Upper Ironstone and Clay. Tealby Limestone. Tealby Clay. Lower or Claxby Ironstone.
			Spilsby Sandstone.

The Carstone, which was doubtfully correlated with the Upper Neocomian of Speeton, was believed by Prof. Judd to be quite unconformably overlain by the Red Chalk. This theory of an

* "On the Strata which form the Base of the Lincolnshire Wolds," Quart. Journ. Geol. Soc. vol. xxiii. pp. 227-251.

† "Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire, with Notes on their Relations to Beds of the same Age throughout Northern Europe," Quart. Journ. Geol. Soc. vol. xxvi. pp. 326-347.

unconformity, however, has not been confirmed by an examination of the numerous sections of the junction that are exposed. The overlap of the Carstone by the Red Chalk, which at first sight seems strongly to support Prof. Judd's view of their relations, appears to be due to the steady attenuation of the Carstone northwards that is shared by all the Secondary rocks of Lincolnshire. On the other hand, the Carstone is found not only to rest upon different members of the Tealby Beds in different parts of Lincolnshire, but to present a strong contrast to all these beds, both in lithological character and in being altogether unfossiliferous, except for the derived fauna, hereafter described. It is, moreover, largely composed of materials, such as flakes and grains of iron-oxide and phosphatic nodules, which there is good reason to believe were derived from the Tealby Beds, and therefore indicate that these latter had suffered considerable erosion before the deposition of the Carstone.

In general the Carstone is a coarse, reddish-brown, ferruginous grit, made up of small quartz grains or pebbles, small well-rolled phosphatic pebbles, and flakes or spherical grains of iron-oxide. In the southern part of Lincolnshire it is thicker than in the north, and the nodules are smaller. Occasionally the almost obliterated form of a bivalve may be detected, but very rarely. In the north the nodules increase in size and abundance as the Carstone thins, and it is not difficult to pick out rolled Ammonites and bivalves. In its upper part the Carstone becomes more clayey, and passes finally into a red clay or marl, in which Belemnites are common, and which forms the base of the Red Chalk. The small particles of quartz, Lydian stone, &c., which make up a large part of the Carstone, range up in gradually decreasing abundance into the lower beds of the Red Chalk. Two or three lines of concretions (not derived, but formed in place in the Carstone) may be traced for many miles at a scarcely varying distance below the Red Chalk.

Eventually the Carstone thins out altogether, and the conglomeratic character then invades the Red Chalk. The nodules which occur in the Red Chalk are similar to those of the Carstone, where the Red Chalk rests on the Neocomian clays, but north of the Humber, where it overlaps the Oolites, are made up fragments of those rocks. The Carstone of South Lincolnshire would thus appear to be the expansion of a "coprolite-bed," and in its behaviour may be compared to the Chloritic Marl and the Cambridge coprolite-bed, or to what takes place on a great scale at the base of the Carboniferous rocks, where the limestone becomes conglomeratic when the red basement-beds are absent.

The outcrop of the Neocomian rocks and their thicknesses in different parts of Lincolnshire are illustrated in the accompanying figures (facing p. 492). The series thins out northwards through the steady attenuation of each member, rather than by a marked unconformity of the beds above, as is seen in the following table of thicknesses :—

	Skegness Boring.	South end of Wolds.		Tealby.	Claxby.	Acre House Mine Shaft	East of Nettleton Lodge.	Nettleton Grange.	Audleby.	Melton Ross.	Elsham.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
Red Chalk.....	10	11	6	5	?	4	4	4		$\frac{1}{2}$ (?)	3-4
Carstone	19 $\frac{1}{2}$	40	25	14	10	10	11	0		0	$\frac{1}{6}$
Tealby Beds	219	135	65	60	68	40	23	10		0	1-3
Spilsby Sandstone... {	Sand 19 Clay 23	50	42	30	7 (?)	35	24	15	9	(about)	10

In the Skegness boring the Tealby Beds consisted chiefly of clay, crowded in some parts with spherical grains of iron-oxide. The Spilsby Sandstone (a very constant bed along the outcrop) was unexpectedly thin, owing apparently to its partial replacement by clay; it was also finer in grain than it is further west.

Section No. 9 (fig. 1) shows the general thicknesses at the south end of the Wolds. In this part a calcareous and ferruginous stone appears in the upper part of the Tealby Beds, and forms a well-marked feature in the hill-sides. The lower part of the clay is crowded with spherical grains of iron-oxide. The Spilsby Sandstone is based by a "coprolite-bed," made up principally of casts of common Kimeridge-clay forms. This nodule band is continued through the whole area, and without doubt indicates the erosion of a portion of the Kimeridge Clay before the deposition of the Speeton Series.

Section No. 8 shows the position of the Tealby Limestone. Though not actually continuous with the ferruginous limestone of the south end of the Wolds, it is similar to it and appears at about the same horizon. The Carstone here begins to assume more distinctly a conglomeratic character; it contains a pebbly band, four or five feet thick, made up of well-rolled nodules of a pale bluish phosphate of lime, a few of which are clearly internal casts of bivalves. The base of the Carstone is seen near Otby (between Sections 8 and 7) to be formed by a nodule-bed, about six inches thick, made up of large rolled phosphatic nodules, which contain casts of Ammonites believed to be of Neocomian species. *Ammonites speetonensis* (?) four specimens, *Am. plicomphalus* (?) one specimen, *Lucina* (?), and others, and a Gasteropod were collected here*, and have been identified by Mr. Sharman. Many of the nodules also contained the spherical grains of iron-oxide so common in the Neocomian clays. The nodule-band rests on pale-blue or grey Neocomian clay crowded with iron-grains.

* Mr. Keeping informs me that he found the following specimens occurring as pebbles in the Carstone at Claxby, about five feet below the base of the Red Chalk:—*Ammonites Deshayesi*, Leym., *A. triplex*, Sow., *Requienia*?, *Astarte*, *Corbula*, *Modiola*, *Myacites*, *Pholadomya*, *Cyprina*, *Teredo*.

Section 6 is taken from the sinking journal of the shaft of the Acre House Iron-mine. The iron-ore occurs at the base of the Tealby Clay. The Carstone is described as resting directly on the Tealby Limestone, the clay with iron-grains of the preceding section being presumably absent. The reason of the thinness of the Spilsby Sandstone is not clear; it preserves its usual thickness at the outcrop close by.

In Sections 5 and 4, the Carstone is highly conglomeratic, and contains numerous nodules ranging up to three quarters of an inch in diameter and imbedded in the usual, gritty and clayey matrix. In the lower part it is more sandy, but its base is concealed.

North of this point there are no sections for some miles, but it is known that the Carstone thins out within a short distance. Eventually the whole Neocomian Series thins out and is overlapped, the last section occurring near Audleby (No. 3). The Red Chalk here comes close down on to the Tealby Limestone, though there is no actual exposure of the junction. Between the two there occur phosphatic nodules similar to those found in the Carstone.

From Audleby northwards the Red Chalk rests on Kimeridge Clay as far as Melton Ross (about six miles), where the Spilsby Sandstone reappears for a short distance (Section No. 2). The base of the Red Chalk here is highly conglomeratic. In addition to the usual quartz-grains, it contains abundance of the phosphatic nodules so common in the Carstone.

Section 1 is taken in the last exposure of Neocomian beds in Lincolnshire. The Red Chalk passes down into a band of yellowish or greenish clayey grit, containing phosphatic nodules and presenting all the characters of true Carstone, except in its thickness, which amounts to only two inches; it rests with a marked unconformity on the Tealby Clay. In a few yards' distance the Neocomian rocks are entirely overlapped.

Where they reappear in Yorkshire they consist of a series of nearly homogeneous clays known as the Speeton Series, and divisible into Upper, Middle, and Lower Neocomian by the fossils*. There are no sandstones at Speeton corresponding to the Carstone or Spilsby Sandstone†, but the latter may be correlated with the lower part of the clay by fossils, as shown by Prof. Judd.

It will be seen from the foregoing sections that the Carstone is persistent, while the underlying Neocomian rocks thin from 261 feet to 47 feet. The disappearance of the Carstone appears to be due merely to a similar thinning away in the same direction. This northerly attenuation is shared also not only by the Red Chalk, but by many of the Secondary rocks as far down as the Lias. The

* Judd, "On the Speeton Clay," *Quart. Journ. Geol. Soc.* vol. xxiv. p. 218 (1868).

† It should be mentioned, however, that near Kirkby Underdale, in Yorkshire, there occurs for a short distance at the base of the Chalk a very ferruginous gritty sand, which, from its resemblance to beds of Neocomian age in Lincolnshire, has been classed in this division. Blake, *Geol. Mag.* dec. ii. vol. i. p. 363, and *Proc. Geol. Assoc.* vol. v. p. 246; and 'Geology of the Country North-east of York and South of Malton' (*Geol. Survey Memoir*), p. 25 (1884).

Oolites and Lias are both at their minimum in the district a few miles north of the Humber, subsequently expanding, as do the Neocomian rocks, in what may be called the Yorkshire basin. It may be supposed that there existed between the Yorkshire and Lincolnshire districts an area of slower subsidence, forming a partial barrier in the Jurassic and Neocomian periods, but overspread subsequently by the waters of the Chalk sea.

The fossil evidence, so far as it goes, seems to indicate that there was considerable erosion of the Speeton Series before the deposition of the Carstone. The fossils found in the derived phosphatic nodules are believed to be Neocomian species, as stated above, though their state of preservation does not admit of this being determined with certainty. The nodules themselves are quite different from those which occur as boulders in the Spilsby Sandstone, and which are known to have been derived chiefly from the Kimeridge Clay; they frequently contain the grains of iron-oxide so common in the Tealby Beds, and resemble in other ways the concretions that are found *in situ* in the Tealby Clay. The grains and flakes of iron-oxide also, which are so abundant in the Carstone, all appear to have been derived from the clay, while the small pebbles of quartz, Lydian stone, &c. have most probably been washed out of the Spilsby Sandstone. The Carstone, in fact, is made up of such materials as would result from the "washing" of a mass of Tealby Clay and Spilsby Sandstone.

In the Secondary rocks lines of erosion are often indicated by bands of rolled phosphatic nodules, these being the only portions of the soft clays that survive redistribution. Thus the break between the Chalk and Gault in the eastern counties is marked by a "coprolite-band," the nodules being imbedded in the base of the Chalk. When the Chloritic Marl comes in, the nodules are scattered through it sporadically. The phenomena are strictly comparable to what takes place in the case of the Carstone.

It would thus seem that the Carstone of Lincolnshire should be regarded rather as the basement-bed of the Chalk than as the top subdivision of the Neocomian. On this view the difficulty of correlating the Lincolnshire and Yorkshire sections is much lessened. The horizon of the Carstone is marked, after the disappearance of the Carstone itself, by a "coprolite-band" in North Lincolnshire, and by an unconformity in Yorkshire; and the Tealby Beds and Spilsby Sandstone become then the equivalents of the Speeton Series, the sandstone having thinned out or been replaced by clay towards the north, as it was also towards the south-east at Skegness.

The correlation of the Lincolnshire with the Norfolk area now becomes a matter of great importance, inasmuch as it determines the relation of the Speeton Series to the Neocomian of the southern counties. The Norfolk series consists at Hunstanton of an upper and lower sandstone separated by a bed of clay, which, however, dies out and leaves the two sandstones in one indivisible mass. The lower sandstone rests on Kimeridge Clay. It has to be

decided whether the impersistent clay is the representative of the Tealby Beds, or whether the whole of the Norfolk series should be correlated with the Lincolnshire Carstone.

A comparison of the thickness of the subdivisions in the two areas would seem to show that this clay is too insignificant to be a representative of the 219 feet of clay proved at Skegness, especially as it thickens steadily southwards throughout Lincolnshire (see figures). The Hunstanton clay is generally about ten feet thick and thins out to the south.

If, on the other hand, the whole of the Norfolk section is taken to represent the Carstone only of Lincolnshire, it must be supposed that the Speeton Series is entirely absent, which at first sight would seem to imply a still more rapid thinning out than the former theory. But on the evidence for an unconformity between the Carstone and Tealby Beds in Lincolnshire it may be supposed that the latter were denuded away in Norfolk before the deposition of the Carstone. It may be mentioned here that boulders believed to be of Spilsby Sandstone occur in the Norfolk Carstone just above the clay-band*. Prof. Judd stated in 1869 that "he considered that the Carstone does not represent the Tealby Series of Lincolnshire, and that it is probably Aptian or Upper Neocomian, but containing in its lowest part fossils derived from the disintegration of Lower Neocomian beds, in the same manner as the deposits of phosphatic nodules at Potton and Upware" †.

The correlation of the Norfolk Carstone, resting (presumably unconformably) on the Kimeridge Clay, with the Upware deposits, which rest with a marked unconformity on Kimeridge Clay and Coral Rag, shows that the older rocks are being overlapped towards the south. This is further indicated by the contained fragments, which include specimens of rocks older in age further to the south. Thus at Hunstanton the derived fauna includes specimens of Lower Neocomian and some Kimeridge-clay forms; further south a few Neocomian, some Portlandian, a *very large proportion* of Kimeridge-clay, and some Oxford-clay forms are found. Similarly the boulders in the Red Chalk in the area between Lincolnshire and Yorkshire, where the Carstone and Speeton Series are absent, are made up of fragments of the Oolitic rocks, with *Ammonites calloviensis* and *Amm. Koenigi* from the Kellaways Rock ‡. It is thus quite intelligible that the Carstone should in that area, where the Speeton Series or its equivalents are well developed, contain only fragments derived from these rocks.

The correlation of the Lincolnshire Carstone with that of Norfolk necessitates the retention of this rock in the Neocomian group as at present defined. At the same time the evidence given above

* W. Keeping, 'The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill' (1883).

† Wiltshire, "On the Red Chalk of Hunstanton," Quart. Journ. Geol. Soc., vol. xxv. p. 192 (Discussion).

‡ Blake, Proc. Geol. Assoc. vol. v. p. 248; and 'Geology of the Country South-east of York, &c.' (Geol. Survey Memoir), p. 18.

indicates that it should be separated from the Speeton Series as a distinct and probably unconformable subdivision. The classification that has been adopted for the map (fig. 2) is shown in the explanation of the Sections.

If this correlation is correct, it follows that the Neocomian rocks of Bedfordshire and of the eastern counties generally are later than the whole of the Neocomian (Speeton Series) of Yorkshire and the greater part of the Neocomian of Lincolnshire. In the south of England, however, there seems to be little doubt that there are equivalents, of the upper portion at least, of the Speeton Series. The fauna of the Upper Neocomian of Speeton is spoken of by Prof. Judd as being "most unmistakably that of the Lower Greensand and Atherfield Clay of the South of England"*. It presents the closest analogy with the Atherfield Clay, but this is believed by Prof. Judd to be due merely to the influence of similar physical conditions on the recurrence of species. There occurs, however, a pebble-bed near the base of the Folkestone Beds, in which fossils derived from the Oolites occur as boulders. This pebble-bed is correlated by Mr. Mejer with the phosphate-beds at Upware, and with the lower beds of the Greensand (Carstone) of Hunstanton†. He further remarks that though in the Isle of Wight the Folkestone Beds and Atherfield Clay have many of the same species, at Godalming they have not a single species in common. If the Folkestone Beds with the pebble-bed are taken as the equivalent of the Lincolnshire Carstone, and the Atherfield Clay as that of the Upper Neocomian of Yorkshire, this difference in their fauna is quite in accordance with the view of the relations of the Carstone as detailed above. The following table shows the suggested correlation of the deposits in these different areas:—

Speeton.	Lincolnshire.	Norfolk.	Bedfordshire.	South Coast.
Absent.	Carstone with derived Neocomian fauna.	Carstone with derived Neocomian fauna.	Sands with derived Oolitic and Neocomian fauna, and indigenous late Neocomian fauna.	Folkestone Beds with pebble-bed containing derived Oolitic fauna, and late indigenous Neocomian fauna.
Upper } Middle } Lower } Speeton Clay.	{ Tealby Beds. { Spilsby Sandstone.	Absent.	Absent.	{ Sandgate beds. ? { Hythe beds. Atherfield Clay.

* "On the Speeton Clay," Quart. Journ. Geol. Soc. vol. xxiv. p. 218.

† 'On the Lower Greensand of Godalming.' By C. J. A. Mejer (Geologists' Association). 8vo. 1869.

North to South.

9. South end of Wolds.

10. Skegness Boring (part).

11. Hunstanton (generalized).

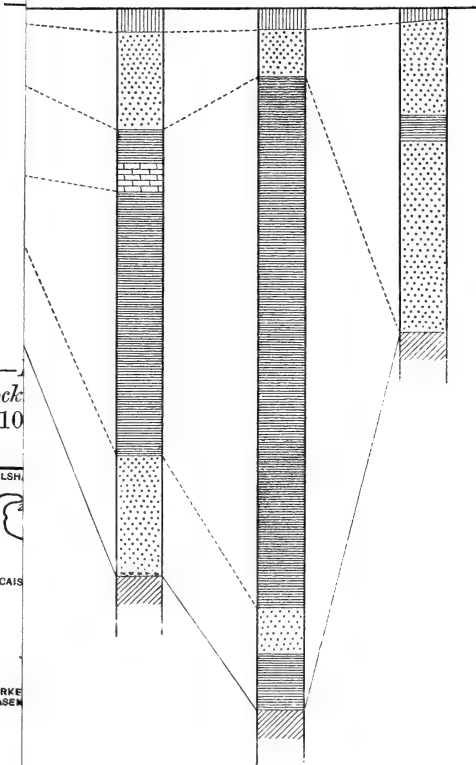


Fig. 2.—
Rock
1-10





Fig. 1.—Comparative Sections of the Lincolnshire Neocomian Rocks from North to South.

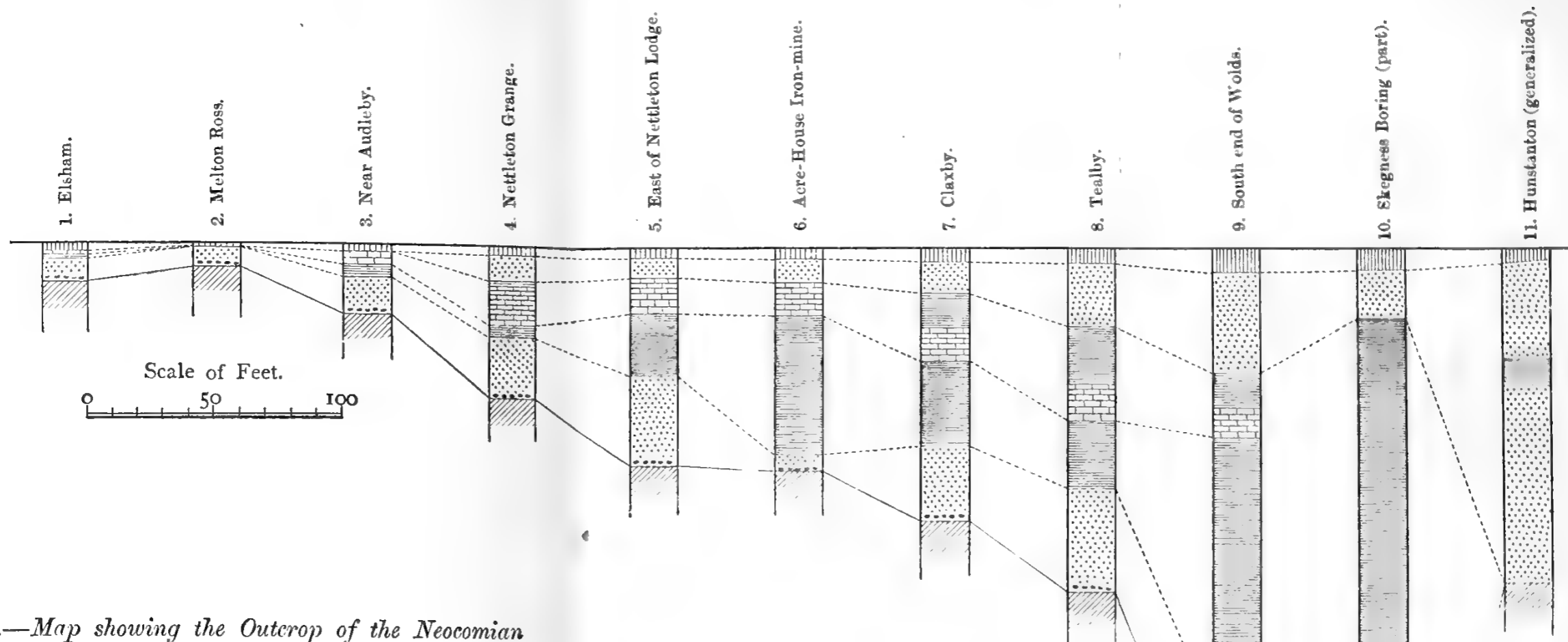
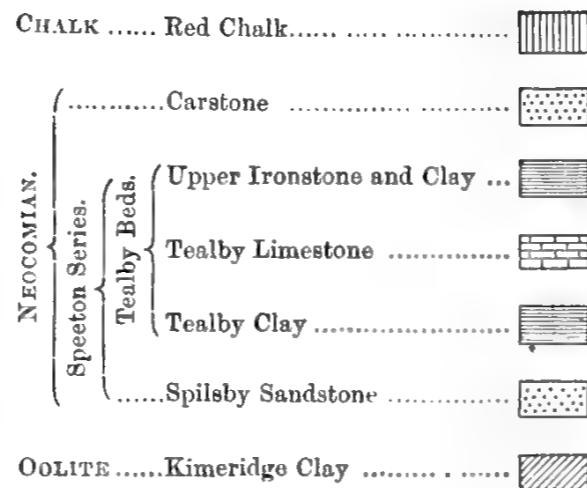
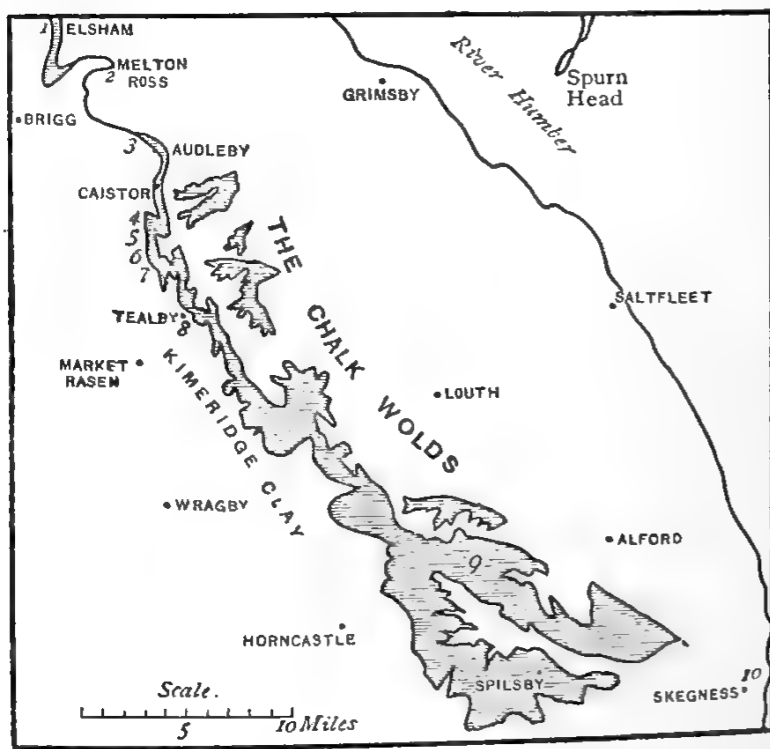
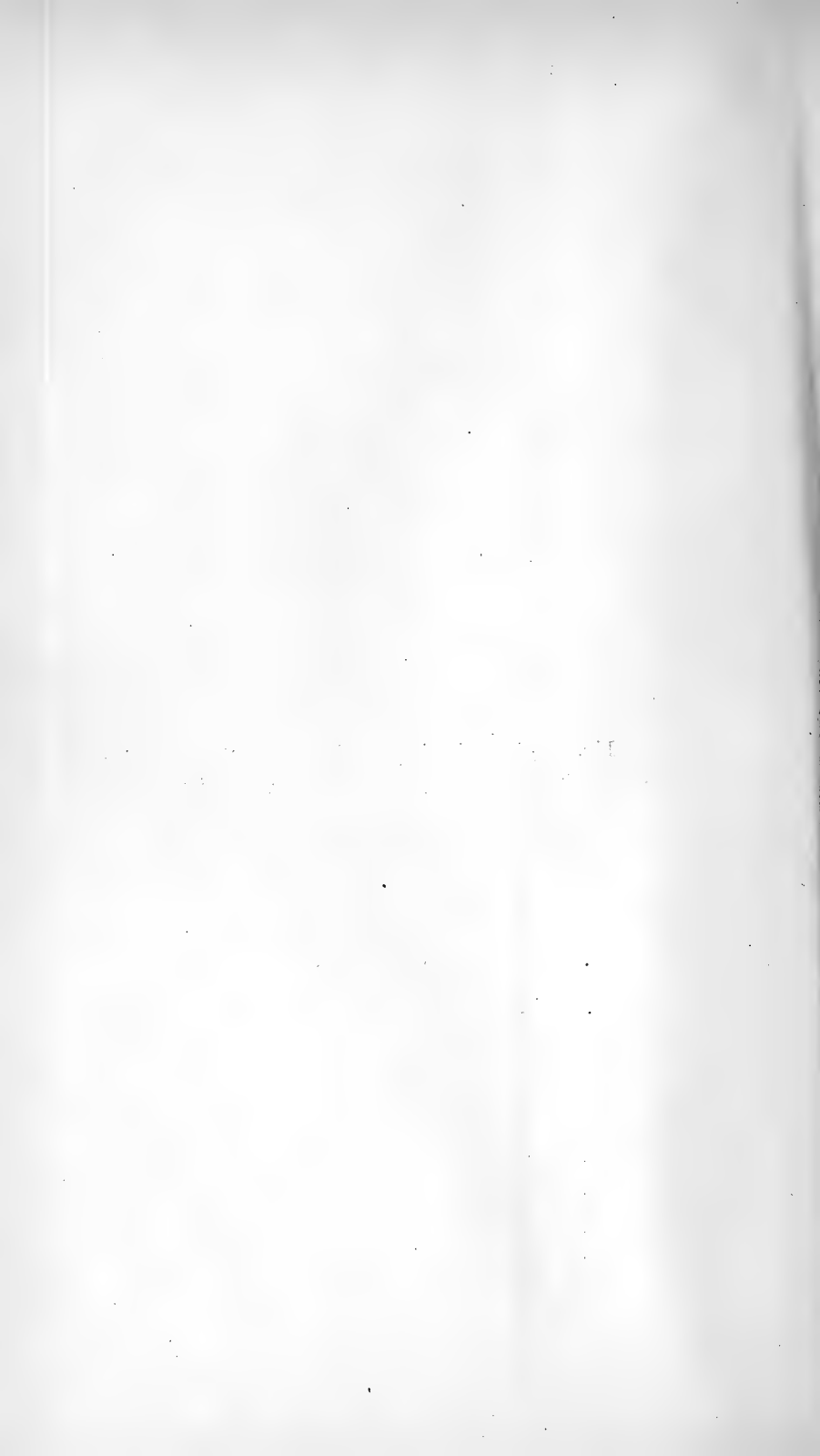


Fig. 2.—Map showing the Outcrop of the Neocomian Rocks in Lincolnshire, and positions of Sections 1-10 (fig. 1).





DISCUSSION.

The PRESIDENT said that he had listened to this paper with great pleasure. The one point of difference between himself and the Author may be easily explained. At the time when he described the structure of the district, the Lower Greensand of the south was regarded as one, but since then the break between the Folkestone Beds and those below has been clearly shown by Barrois, Mejer, and others. He was quite prepared to accept the Author's general conclusions.

Professor HUGHES considered the paper a valuable contribution to the geology of East Anglia, and hoped that the Author would press the legitimate conclusion that the Carstone series was the basement-bed of the Cretaceous, and would abolish the bracket which in his diagram linked it to the bed below, whether called Tealby Series or Neocomian. He thought the Author might extend the story of the manner in which the Lower Greensand, or Carstone, creeps transgressively over the older formations, if the few inches of sand which rested on the Wenlock in the Ware boring should, as he believed, turn out to be the geological equivalent of the Carstone.

Mr. WHITAKER stated that he did not know the district referred to by the Author, but that he knew the north-western part of Norfolk. He agreed as to the conformity at Hunstanton between the Red Chalk and the Carstone. The occurrence of stone was more or less a matter of accident, and the presence of about 10 feet of clay between the sandy beds and the Red Chalk in the well at Holkham perhaps indicated the presence there of Gault. The conformity between the Carstone and the Red Chalk was a singular thing; in Bedfordshire the Gault sometimes scoops into the Lower Greensand. Where there is a considerable absence of beds, as where Red Chalk rests on Carstone, you may have conformity just where one would least expect it. He was doubtful as to the occurrence of the Carstone in the boring at Ware.

The PRESIDENT called attention to the interesting section at Skegness where the Neocomian clays thickened out so remarkably, and he observed that they continued their increased development to the eastward in Germany, where they are known as the "Hilsthon." Their thickness at Skegness was the more remarkable, considering the shortness of the distance from their outcrop in the Downs, where they were of insignificant thickness.

The AUTHOR said that, as regarded the bed in the boring at Ware, if it were Carstone it proved his point. He gave particulars as to the section at Skegness, and stated that it was over 250 feet to the base of the Spilsby Sandstone, which had dwindled down to a few feet in thickness and had been in part replaced by clay. The Spilsby Sandstone would seem to have been a shore-deposit.

40. *On some CUPRIFEROUS SHALES in the PROVINCE of HON-PEH, CHINA.* By H. M. BECHER, Esq., F.G.S., A.R.S.M. (Read June 23, 1886.)

IN the month of July 1885, the writer was asked to accompany a Chinese gentleman, proceeding from Shanghai, to visit certain deposits of copper-ore reported to be very rich and extensive, and occurring on some property up the Yangtse river. Specimens of the ore had been sent to Shanghai and were given to the writer for inspection. These consisted of mixed ore of copper of dark brown colour, being mostly impure oxides with a little unchanged sulphide permeated by streaks of carbonate. The mineral was very heavy, and showed by a rough test about 70 per cent. of metallic copper. The most interesting feature, however, was the external appearance of the pieces, one of which was intact as taken from the earth near the surface, showing a striking resemblance to the well-known form of petrified wood, and suggesting the possible association of organic agency in its origin. This peculiarity of course dispelled the first assumption of large veins, though adding to the interest of investigating the mineral source, which proved to be near the open Port of I-Chang, on the Yang-tse-Kiang, about 1000 miles from the sea.

The country surrounding I-Chang, on the western border of the province of Hon-peh, is very mountainous, being on the confines of the extensive ranges through which the river Yang-tse-Kiang here emerges from its eastward course through the province of Setchuan. The low hills in the immediate vicinity of I-Chang are composed of reddish sandstone and conglomerate beds dipping very slightly to S.E.; but the higher mass of hills to the west is of Lower Palæozoic and Carboniferous (?) rocks, in which thick beds of limestone are most conspicuously prominent, rising to a height of 5000 feet above the river. Thus, going westwards from I-Chang, at a distance of about ten miles, the limestones appear from under the sandstone series, the lowest beds of the latter consisting for the most part of limestone and quartzite pebbles, while peculiar beds of brecciated calcareous conglomerates overlies the blue-grey crystalline limestone, almost horizontally, to a thickness of some hundreds of feet.

The relative position of these rocks is not quite distinctly evident, as, though the Limestone series is proved by its fossils to be of Palæozoic (presumably Precarboniferous) age, and is overlain to the westward by a great shale series, which in some parts contains coal-bearing measures, it is not certain whether the sandstones (containing no coal) to the eastward are conformable or contemporaneous with the said shales, their lithological character being entirely different. Each of these three series is of great thickness, *i. e.* many thousands of yards, forming high cliffs, gorges, and sheer declivities, according to the relative nature of the rocks and the circumstances of denudation. The upper beds of the Great Limestone, when they begin to give place to the shales, contain several bands full of

well-preserved fossils, amongst which are gigantic specimens of *Orthoceras*.

At a distance of about 50 miles west of I-Chang, the Great-Limestone series begins to be overlain by shales and arenaceous beds interstratified with thinner limestones, the latter at first predominating, with a general strike N.W. and S.E., dipping S. and S.W. at high angles and sometimes folding over in anticlinals. These rocks are more disturbed than the thick limestones, but not faulted or showing any intrusions of igneous rocks. Further west the series increases in thickness, and shales predominate, having a uniform characteristic red-brown colour with occasional greenish-grey patches. Some of these shales are slightly micaceous, others contain small cavities filled with crystallized calcite.

In the valley of Lukaho patches are found in which the shales are impregnated more or less with minerals of copper, the beds containing this metal being of the grey colour above noticed, regularly intercalated with the red series and otherwise undistinguished from these. The commonest form of occurrence is that of light green films and specks of malachite or chrysocolla in the cracks of cleavage and stratification of the soft argillaceous rock, which is very friable on weathered surfaces. Another form is a siliceous band, containing specks of cuprite with the green oxydized minerals, also conformable with the shales, but of irregular extension and more contiguous to the calcareous and sandy beds. Accompanying both these, occasional lumps of comparatively pure copper-ore are found enclosed in the soft strata as in actual clay-seams, and it is this latter form of occurrence which must be the origin of the peculiar wood-shaped specimens examined at Shanghai and mentioned above. The extent and value of these cupriferous patches, hardly to be called metaliferous deposits, could only be roughly estimated from the appearance of numerous indications on the outcrops, none of which had been opened up. In one case only was there evidence of continuity along the strike of the strata up a hillside for a distance of some 200 yards, and from this the richest specimens were obtained; but the bed-rock covered with detritus was not exposed sufficiently to give the size of the impregnation in section. In other places the shales showed copper coloration for a thickness of from 1 to 3 or 4 feet, the percentage of the metal appearing to the eye (unchecked as yet by any assays) from a fraction of one to five per cent. The siliceous material showed the nearest approach to anything like vein-stuff, the actual richness of which (though certainly not high) could only be ascertained by chemical test.

The origin of these cupriferous patches, although not to be definitely traced by so cursory an inspection, must be ascribed to the redeposition of the metal by infiltration of solutions derived from other sources of unoxidized minerals in the adjacent rocks; and as the district seems to be devoid of any mineral veins, or even of "pockets" of the ordinary metallic sulphides in the limestones, it seems probable that the primary sources of the metal must have been of sedimentary origin.

In the North of England the same system of rocks is often classified thus :—

- | | | |
|------------------------|---|-----------------------|
| 1. Coal-measures | { | (c). Upper measures. |
| | { | (b). Middle measures. |
| | { | (a). Lower measures. |
2. Millstone Grit.
 3. Yoredale Rocks (Upper Limestone-shales).
 4. Carboniferous, Mountain, or Scar Limestone.
 5. Lower Limestone-shales.

The Coal-measures and the Millstone Grit of the two countries may be regarded as equivalent, though the "Upper red beds (b)" of Scotland are absent in the N.E. of England.

The Carboniferous Limestone series of Scotland and the Yoredale Rocks of England are, in part, parallel deposits, but not wholly, for the base of the former series, when traced southwards across the border into Northumberland, has part of the Yoredales beneath it*. Hence it follows that the lower portion of the Yoredale Rocks is parallel with the upper portion of the Calciferous Sandstones, and that the Scar Limestone and Lower Limestone-shale are more or less equivalent to the main portion of the same series.

But the term Yoredale scarcely applies in Northumberland, and the Geological Surveyors group the whole of the rocks below the Millstone Grit as the "Carboniferous Limestone Series" in the maps of that county. The upper portion of this group, occupying the position of the Yoredales, is very different in character from and much thicker than the latter, as seen in their typical development in Yorkshire; and the lower portion of the group, more or less equivalent to the Scar Limestone, is virtually a slightly modified southward extension of the Calciferous Sandstones of Scotland. This fact had been noticed by other observers before the official survey of Northumberland; perhaps first by our old friend the late Mr. George Tate, of Alnwick, who proposed the following subdivision of this portion of the series †:—

Calcareous group.
Carbonaceous group.
Tuedian beds.

Prof. Lebour ‡ has suggested a modification of this classification by including Tate's Calcareous and Carbonaceous groups in one division under the name "Bernician," the term Tuedian being retained by him for the lowest member of the series.

Mr. Hugh Miller, in the 'Encyclopædia Britannica,' adopts and elaborates Mr. George Tate's scheme of arrangement. We are

* We owe this information to the officers of the Geological Survey of Scotland.

† 'History of Alnwick,' vol. ii. p. 444 (1869); Nat. Hist. Trans. Northumb. and Durham, 1876, pp. 8 & 9; and Proceed. Berwicksh. Nat. Club, vol. iv. p. 151, and vol. x. p. 315.

‡ 'Outlines of the Geology of Northumberland,' 8vo, 1878.

favoured by him with the following synopsis of the Carboniferous strata of Northumberland * :—

CARBONIFEROUS LIMESTONE SERIES.

Northumbrian Type.

Upper Limestone Series	}	Felltop Division : between the Millstone Grit and the zone of the Great Limestone: Sandstones and Shales; one or more beds of Marine Limestone; some Coals. (450 to 1200 feet.)
		Calcareous Division: from the Great Limestone down to the bottom of the Dun Limestone or Redesdale Limestone. Many beds of Marine Limestone: Sandstones and Shales; some Coals. (1300 to 2500 feet.)
		Carbonaceous Division: the Scremerston beds of North Northumberland; beds prevalently Carbonaceous; Limestones, chiefly thin, many of them containing vegetable matter; Coals. (800 to 2500 feet.)
Lower Limestone Series	}	Tuedian Division.
		Upper Tuedian or Fell Sandstone Group. Great zone of massive grits (Larriston Fells, Bewcastle Fells, Peel Fell, Simonside and Harbottle Hills, Chillingham, &c.). Shales partly greenish and reddish; Coals few, thin, and in many districts absent. (600 to 1500 feet.)
		Lower Tuedian or Cement-limestone Group: cementstones passing (at Rothbury and Bewcastle) into Limestones; Coals very rare; many of the Shales and Sandstones coloured. (500 to 2000 feet.)
		Basement Conglomerates (Upper Old Red Sandstone); local.

CARBONIFEROUS LIMESTONE SERIES.

Scotland—Northumberland—Yorkshire.

Scottish Type.

Northumbrian.

Yorkshire.

Carboniferous Limestone Series.....	}	Upper Limestone Group.	}	Upper part of the Upper Limestone Series.	}	Carboniferous Limestone Series, including the beds between the Little Limestone and the Millstone Grit, the Yoredale Beds, and the Lower Limestone-shale.
		Middle or Coal and Ironstone Group.				
	}	Lower Limestone Group.	}	Lower part of the Upper Limestone Series, together with the Lower Carb. L. Series, including Basement-beds.	}	
Calciferous Sandstone Series		Upper or Cementstone Group.				
	}	Lower or Red Sandstone Group.	}		}	

We cannot go further into this matter just now, and we have, perhaps, said enough to show that, in using the term Yoredale for the whole of the North of England in the following remarks and Tables, we do so in a somewhat conventional sense, so far as it relates to Northumberland. It may be added that Ostracoda are so plentiful in these strata, and occur on so many horizons, that the

* Encycl. Britann. 9th edit. vol. xvii. p. 574.

stratigraphical succession of their different groups of species or faunas is a subject well worth working out in detail; and this we hope some time to do with the help of our Geological-Survey friends.

In the centre and south of England,—that is, south of Derbyshire,—the Yoredales are absent, or cease to be of divisional importance in the Carboniferous series, so that the arrangement of formations there generally followed is this:—

Coal-measures.
 Millstone Grit.
 Upper Limestone-shale.
 Carboniferous Limestone.
 Lower Limestone-shale.

Unfortunately we have much less material of the Ostracodous kind from the south of England than we have from the north, and from Scotland, and most of what we have is from the Carboniferous Limestone, there being little from the Coal-measures, and nothing from the Millstone Grit or the Lower Limestone-shale. For this reason, the distribution of species in the appended Table I. (facing p. 506), is shown in two columns only—Carboniferous Limestone and Coal-measures.

For the same reason the Lower Limestone-shale is left out of the Table in “England North,” as we have nothing from localities therein. And, as we have not been able to determine any species from the Millstone Grit either in England or Scotland, that formation is not represented. See p. 514.

All our Irish specimens are from the lower portion of the series, hence the distribution in that country is given in a single column. ⁴

In regard to the geographical divisions used in the Table, “Scotland East” includes Fife, Kinross, Linlithgow, Mid and East Lothian, Berwickshire, and Roxburghshire. “Scotland West” includes the country to the west of that area: namely, Lanarkshire, Stirlingshire, Renfrewshire, Ayrshire, &c.

“England North” takes in Lincolnshire, Notts, Derbyshire, North Staffordshire, and the counties to the north; also the Isle of Man. “England South” embraces the rest of the country southward, including South Wales.

III. STRATIGRAPHICAL DISTRIBUTION OF THE OSTRACODA.

I. SCOTLAND.

§ 1. South of the Firth of Forth, the Upper Old Red is described by Dr. A. Geikie * as passing upwards into the lowest beds of the Carboniferous Series without any signs of break or unconformity. Probably these are the lowest and oldest Carboniferous strata in Scotland; but there are no Entomostraca recorded from them.

In Fife, where the Lower Carboniferous or Calciferous Sandstone series is very thick, the basal beds are never seen, though there are

* Geol. Survey Mem. on East Lothian, p. 27 (1866).

nearly 4000 feet of strata exposed below the Carboniferous Limestone series. In the lowest of these strata, the first Ostracod to appear is a very simple *Beyrichia*, identified with *B. subarcuata*. Fifty feet or so higher up is a shale containing *Carbonia fabulina* and *C. Rankiniana*. A few feet further up still, in a "cement-stone," *B. subarcuata* again appears along with *Leperditia Okeni* and *Bairdia nitida*. These are the earliest traces of Ostracoda in the Carboniferous Series of the east of Scotland that have come under our observation.

A few hundred feet higher up—though still from 3200 to 3500 feet below the Carboniferous Limestone series, and in a section where several thin limestones with marine fossils come in, the following species are found, and they may probably be taken as representative of the earliest important group of Carboniferous Ostracoda in Scotland:—

<i>Leperditia Okeni</i> *.		<i>Bairdia plebeia</i> .
— <i>scotoburdigalensis</i>.	|	— <i>Hisingeri</i> .
<i>Beyrichia subarcuata</i> ?	|	— <i>siliquoides</i> .
—, sp.	|	— <i>præcisa</i> .
<i>Kirkbya spiralis</i>.	|	— <i>subcylindrica</i> ?
— <i>plicata</i>.	|	<i>Macrocypris Jonesiana</i> .
<i>Cytherella extuberata</i>.	|	<i>Argillecia æqualis</i> .
— <i>attenuata</i>.	|	<i>Aglæia cypridiformis</i> .
<i>Carbonia subula</i>.	|	<i>Cythere</i> ? <i>intermedia</i> .

Carbonia subula occurs in this series of strata, but not associated with the other species of the list.

For the next 1000 feet or more upward, Ostracoda appear and reappear time after time, and in great individual abundance. Species, however, are not numerous. Among the commonest forms are *Leperditia scotoburdigalensis*, *Beyrichia subarcuata*, *Cytherella extuberata*, and *C. attenuata*. On some horizons they are joined by *Kirkbya spiralis* and *Cythere* ? *superba*, and perhaps one or two others. At one spot, in a "cement-stone," these species give place to *Leperditia Okeni*, *Beyrichiopsis fimbriata*, a *Cytherella*, and one or two *Bairdia*. Besides, at intervals, those Coal-measure Cytherids (?), *Carbonia fabulina* and *C. Rankiniana*, keep coming in along with *C. subula*. The *Leperditia* and other species generally go out as these appear, though not in all cases.

Above all this, near the middle of the Calciferous Sandstones (speaking of Fife), in a thick marine shale with Crinoids and numerous other fossils are these species:—

<i>Leperditia Okeni</i>.	|	<i>Bairdia plebeia</i> .
<i>Beyrichia radiata</i>.	|	— <i>Hisingeri</i> .
— <i>subarcuata</i> ?	|	— <i>brevis</i> .
<i>Cytherella</i> , 2 spp.	|	— <i>subelongata</i> .

Then follow more appearances of *Lep. scotoburdigalensis* and its associates before mentioned,—though not all of them, for *Kirkbya spiralis*,

* For the authorities of species, see Table II. at the end.

Cytherella extuberata, and *C. attenuata* disappear,—until the Carboniferous Limestone series is approached, when in the thin limestones and associated shales begin to be seen species that are commoner in the beds above.

These remarks relate solely to what has been observed in the Lower Carboniferous of Fife. In equivalent deposits in Mid-Lothian and Linlithgowshire Ostracoda occur in great abundance in some places, notably at the classical locality of Burdiehouse; but the general sequence of the record is less complete, and no other species have been observed.

§ 2. In the south west of Scotland, Dumfriesshire and Ayrshire excepted, the Calciferous Sandstones contain few fossils of any kind, and the only Ostracods recorded from them are *Leperditia Okeni* and *L. subrecta*, from the Lower or Red Sandstone group (a) of the series. These two species are thus probably on a lower horizon than any noticed in Fife, and hence are the first occurring and oldest of known Carboniferous Ostracods.

From low down in the Calciferous Sandstones of Dumfriesshire and Ayrshire, though evidently in the Cement-stone group (b), we have the following species:—*Lep. Okeni*, *Beyr. subarcuata*?, *Argillœcia æqualis*, *Bairdia plebeia*, *B. Hisingeri*, *B. brevis*, and *B. submucronata*.

From a group of limestones higher in position, in Dumfriesshire, a more numerous suite of species occurs, including:—*Kirkbya umbonata*, *K. costata*, *Cytherella valida*, *C. Benniei*, *Macrocypris Jonesiana*, *Bythocypris bilobata*, *Cythere?* *cuneola*, *C.?* *cornigera*, *Bairdia grandis*, *B. Hisingeri*, *B. amputata*, *B. ampla*, and some others.

Lastly, in Roxburghshire, these beds become richly fossiliferous in Ostracoda. Washings of various shales and numerous mounted specimens kindly sent us by the Geological Survey of Scotland from localities in that county have given us the following list of species:—

<i>Leperditia Okeni</i> .	<i>Cytherella extuberata</i> .
— suborbiculata.	— attenuata.
<i>Beyrichia radiata</i> .	—, sp.
— subarcuata?	<i>Cythere?</i> <i>intermedia</i> .
— intermedia? *	<i>Argillœcia æqualis</i> .
— craterigera.	<i>Bythocypris bilobata</i> .
<i>Beyrichiopsis fimbriata</i> .	— sublunata.
— fortis.	<i>Bairdia Hisingeri</i> .
<i>Kirkbya plicata</i> .	— plebeia.
— spiralis.	— ampla?
— costata.	— subelongata.
— umbonata?	— submucronata.
<i>Carbonia fabulina</i> .	<i>Cythere</i> , sp.

The *Carbonia*, although apparently estuarine, curiously occurs here with several of the more decidedly marine forms.

Of the species we have mentioned as found in the Calciferous Sandstone series, the following appear to be confined to it:—*Beyrichiopsis fortis*, *Kirkbya spiralis*, *Cytherella extuberata*, *C. attenuata*, *Bythocypris sublunata*, *Argillœcia æqualis*, *Aglaiia cypridiformis*,

* A Silurian species.

Bairdia nitida, *B. præcisa*, and *Cythere? superba*; while *Beyrichia craterigera*, *Kirkbya costata*, *K. plicata*, and *Macrocypris Jonesiana* are almost peculiar to it, and certainly highly diagnostic of the series.

§ 3. *Carboniferous Limestone Series of South-west Scotland*.—The shales connected with the limestones of the Lower beds (*a*) of this series have yielded a great number of Ostracoda—more species, in fact, than any other portion of the Carboniferous system either in Scotland, England, or elsewhere. The following list includes the most common and characteristic forms from these limestones and shales:—

Cypridina primæva.	Beyrichia bituberculata.
— Phillipsiana.	— ventricornis.
Entomoconchus Scouleri.	Kirkbya permiana.
Polycope simplex.	— umbonata.
— Youngiana.	— Urei.
Cytherella recta.	— spinosa.
— scrobiculata.	— oblonga.
Leperditia Okeni.	Bythocypris Phillipsiana, var. carbonica.
— suborbiculata.	Bairdia plebeia.
— oblonga.	— curta.
— compressa.	— Hisingeri.
— Armstrongiana.	— brevis.
Beyrichia fastigiata.	— amputata.
— multiloba.	— submucronata.
— radiata.	— subelongata.
— tuberculospinosa.	— ampla.
— reticosa.	Cythere? cuneola.
— Bradyana.	— ? cornigera.

As peculiar to this portion of the series may be mentioned:—*Cypridina Hunteriana*, *Cypridellina intermedia*, *Bradycinetus Rankinianus*, *Entomoconchus globosus*, *Polycope Youngiana*, *Cytherella brevis*, *C. concinna*, *C. obesa*, *C. rotundata*, *Leperditia compressa*, *L. Armstrongiana*, *L. Bosquetiana*, *Beyrichia colliculus*, *B. reticosa*, *B. varicosa*, *Bairdia amputata*, *B. grandis*, *B. ? circumcisa*, *B. legumen*, and *Bythocythere Youngiana*; several of these are rare.

The middle portion of the series (*b*), containing the workable coals and ironstones, which form the “Lower Coal-measures” of Scotch geology, yield few Ostracods; and the most common are two Upper-Coal-measure forms. These four species occur in it:—*Leperditia Youngiana*, *Beyrichia* sp., *Carbonia fabulina*, *C. Rankiniana*.

In the Upper-Limestone group of this series (*c*) many of the species belonging to the Lower group (*a*) are recurrent, and a few appear for the first time. The most common forms are:—

Cypridina Youngiana.	Cytherella Benniei.
Leperditia Okeni.	— æqualis.
— suborbiculata.	— obliqua.
Beyrichia radiata.	— scrobiculata.
— bituberculata.	Bairdia plebeia.
— multiloba.	— Hisingeri.
— ventricornis.	— curta.
Kirkbya rigida.	— siliquoides.
— Urei.	Cythere? cuneola.
— permiana.	— ? cornigera.
Cytherella recta.	

The species peculiar to these beds are:—*Cypridina Youngiana*, *C. Grossartiana*, *C. Thomsoniana*, *Cytherella obliqua*, *C. æqualis*, *Beyrichia fodicata*, *B. bicasa*, *Kirkbya rigida*, and *Youngia rectidorsalis*.

Then comes the series of sandstones, grits, shales, and fireclays, with a thin coal or two, representing the Millstone Grit. From these beds we have no Ostracoda.

Above them follow the Coal-measures proper, consisting of a Lower series (*a*), containing all the workable coals; and an Upper series (*b*) of red sandstones, shales, marls, and fireclays, with Carboniferous fossils. In the Lower series *Beyrichia arcuata*, *Carbonia fabulina*, *C. Rankiniana*, and *C. pungens* are the common Ostracoda. *Cypridina radiata* and *Carbonia? bairdioides* also occur rarely. In the Upper series (*b*) *C. fabulina*, *C. Rankiniana*, and *C. pungens* are found abundantly at an horizon about 400 feet from the highest beds. These are the last occurring Carboniferous Ostracods in Scotland that we have seen. The next appearance of representatives of their tribe is in the Lower Permian Limestone of Durham, where a group of seven species is found, six of which are Lower-Carboniferous forms; but these *Carboniæ* are not among them.

2. ENGLAND.

§ 1. In the north of England the lowest horizon from which we have Ostracoda is somewhere near the base of the Scar Limestone, as it occurs in North Lancashire and Westmoreland, and the Lower Carboniferous beds in Cumberland and Northumberland, which are probably nearly equivalent in position, though very different in character. From this or these horizons come the following more common species:—

Cypridina brevimentum, *Cypridinella Cummingii*, *C. superciliosa*, *Cypridellina Burrovii*, *Cyprella chrysalidea*, *C. annulata*, *Polycope Burrovii*, *Entomoconchus Scouleri*, *Entomis Burrovii*, *E. Koninckiana*, *Cytherella valida*, *C. scrobiculata*, *C. extuberata*, *Leperditia Okeni*, *L. suborbiculata*, *L. acuta*, *L. scotoburdigalensis*, *L. subrecta*, *Beyrichia craterigera*, *B. crinita*, *B. radiata*, *Beyrichiopsis subdentata*, *B. fimbriata*, *Kirkbya costata*, *K. spiralis*, *K. umbonata*, *Argillæcia æqualis*, *Macrocypris Jonesiana*, *Bairdia Hisingeri*, *B. curta*, *B. plebeia*, *B. submucronata*, *B. subelongata*, *Bernix Tatei*, &c.

Higher in the limestone are also found, somewhat plentifully, *Kirkbya permiana*, *Leperditia Armstrongiana*, *Bythocypris bilobata*, *Xestoleberis? subcorbuloides*, *Bairdia amputata*, &c.

The species peculiar to this portion of the series south of the Border are:—*Cypridina brevimentum*, *Cypridinella Cummingii*, *C. monitor*, *Cypridellina Burrovii*, *Entomoconchus Scouleri*, *Entomis Burrovii* (and other of the Cypridinidæ), *Cytherella valida*, *Leperditia subrecta*, *L. Armstrongiana*, *L. obesa*, *Beyrichia longispina*, *B. tuberculospinosa*, *B. Holliana*, *B. crinita*, *Beyrichiopsis subdentata*, *B. fimbriata*, *Kirkbya tricollina*, *K. spiralis*, *Argillæcia æqualis*, *Macrocypris Jonesiana*, *Aglæia cypridiformis*, *Bythocythere antiqua*, *Cythere? Kirkbyana*, *C.? gyripunctata*, *Darwinula berniciana*, and *Xestoleberis? subcorbuloides*.

The calcareous shales of the Yoredale rocks contain many species. In the lower beds there occur some of the more characteristic forms of the Lower Carboniferous, in the two northerly counties at least, such as *Cytherella valida*, *Beyrichia craterigera*, and *Kirkbya costata*; but these do not range very far upward.

The forms peculiar to the Yoredales are:—*Leperditia lovicensis*, *Beyrichia ventricornis*, *B. bituberculata*, *Kirkbya Urei*, *Bythocythere Youngiana*, *Bythocypris Phillipsiana*, var. *carbonica*, *Phreatura conicina*, *Cythere? cornigera*, *Bairdia legumen*, and *B. mucronata*.

We have no determinable species from the Millstone Grit.

From the Lower Coal-measures (*a*) have been obtained *Beyrichia arcuata** and *Carbonia? sp.*

From the Middle or main group of the Coal-measures (*b*) the last-named *Beyrichia* is a common fossil; so also is *Carbonia fabulina*. Of less common occurrence are *Philomedes elongata*, *Carbonia Rankiniana*, *C. secans*, *C. scalpellus*, and *C. Wardiana*.

Then in the Upper Coal-measures (*a*) reappears *Beyrichia subarcuata*, and in the "Spirorbis Limestone" of this group *Leperditia inflata*. These seem to be the last occurring Carboniferous Ostracods in England.

§ 2. Of the area of "England South" our materials are not as yet sufficient to allow anything like a complete sketch to be given of the vertical distribution of the species.

[NOTE.—Since this paper was written we have examined and described † a set of Carboniferous Ostracoda from the Gayton Boring, Northamptonshire. These Ostracods were obtained, at a depth of over 700 feet from the surface, in shaly beds, evidently identical with the Lower Limestone-shale. The shales were kindly supplied by Mr. H. J. Eunson, F.G.S. Six species were determined (one of which was new to us, and the other five were well-known Lower Carboniferous forms of Scotland and the North of England), namely, *Kirkbya variabilis*, *K. plicata*, *Cytherella extuberata*, *C. attenuata*, *Bythocypris sublunata*, and *Macrocypris Jonesiana*.

Quite recently Mr. E. Wethered, F.G.S., of Cheltenham, has favoured us with specimens from the Lower Limestone-shale of the Forest of Dean. Curiously enough these specimens are almost exactly similar in species and individual abundance to those of the Gayton Boring.

From the Forest of Dean came *Kirkbya variabilis*, *K. plicata*, *Cytherella extuberata*, *Bythocypris sublunata*, and *Darwinula berniciana* (?).]

In the Carboniferous Limestone of Shropshire, South Wales, and

* *B. arcuata* is said to occur at Shaly Brow, in the Wigan coal-field, in the roof of one of the Gannister coals, where it is associated with *Aviculopecten papyraceus* and *Goniatites Listeri*. It would be of interest to have this corroborated, and to learn whether it occurs in other of the *Aviculopecten*-bands of the Lower Coal-measures, and just of as much interest to know if other Ostracods are found with it under these conditions.

† Geol. Mag. dec. iii. vol. iii. 1886, p. 248, pl. 7.

Somerset are found *Leperditia Okeni*, *L. parallela*, *L. acuta*, *Beyrichia arcuata* (?), *B. sp.*, *Kirkbya plicata*, *K. costata*, *Moorea tenuis*, *M. obesa*, *Bythocypris bilobata*, *Argilloecia æqualis*, *Cythere? lunata*, *C.? pyrula*, *C.? Moorei*, *C.? cornigera*, *C.? thraso*, *Bairdia curta*, *B. plebeia*, *B. brevis*, and *B. Hisingeri*.

We have nothing in the south representing the large groups of species found in the Yoredale Rocks of the north of England, or of the Carboniferous Limestone series of Scotland.

From the Coal-measures of South Wales we have *Carbonia Agnes*, *C. Evelinæ*, and *C. sp.*; and from the "Spirorbis Limestone" of the Midland counties *Leperditia inflata*.

IV. IRELAND.

The distribution of the Carboniferous Ostracoda in Ireland (see Table II.) requires further work. The Mountain-limestone near Cork and elsewhere is known to be very rich in these fossils, as are also some parts of that formation in the Isle of Man. The Lower Carboniferous Shales are rich at places in Ireland (see M'Coy's Synops. Charact. Carbonif. Fossils, Ireland, and Ann. & Mag. Nat. Hist. ser. 3, vol. xviii. pp. 40-51).

V. DISTRIBUTION OF OSTRACODA IN PERMIAN STRATA OF ENGLAND.

To render this sketch of the vertical distribution of Ostracoda in the Upper Palæozoic rocks more complete, we continue it up to the Permian series, into which eleven of the Carboniferous species are known to range.

In the Lower Magnesian Limestone of Durham and Yorkshire we find the following species:—*Kirkbya permiana*, *Bairdia plebeia*, *B. Hisingeri*, *B. ampla*, *Macrocypris Jonesiana*, *Cythere intermedia*, *C.? inornata* (?), and *Cytherella nuciformis*?

In the Middle Magnesian Limestone of Durham occur:—*Cypridina primæva*, *Kirkbya permiana*, *Bairdia plebeia*, *B. Hisingeri*, *B. acuta*, *B. Kingii*, *B. bernicensis*, *B. rhomboidea*, *B. amputata*, *Macrocypris Jonesiana*, *Cythere? intermedia*, *C.? Morrisiana*, and *C.? Geinitziana*.

And in the Upper Magnesian Limestone of Durham we have as the last Palæozoic representatives of the order:—*Kirkbya permiana*, *B. plebeia*, *B. grandis*, *B. ampla*, *B. acuta*, *Cythere? Morrisiana*, *C.? Kutorgiana*, *C.? Geinitziana*, *C.? biplicata*, *C.? inornata*, and *Cytherella nuciformis*:

These occurrences in the Permian series represent a range of about 400 feet. The Ostracods are always found along with the marine Mollusca and other fossils of the Magnesian Limestone; but where the last representatives of the Mollusca are seen in the highest beds of the series, no Ostracoda are found with them.

The Carboniferous species recurrent in Permian strata are:—*Cypridina primæva*, *Kirkbya permiana*, *Bairdia plebeia*, *B. ampla*, *B. Hisingeri*, *B. amputata*, *B. grandis*, *Macrocypris Jonesiana*, *Cythere? intermedia*, and (in the Zechstein of Europe) *Bairdia mucronata* and *B. subgracilis*.

VI. RANGE OF BRITISH CARBONIFEROUS OSTRACODA IN NORTH AMERICA AND EUROPE.

§ 1. Among the British species already found in other countries, perhaps *Cytherella Benniei* and *C. concinna* enjoy the greatest range, as they are met with in the Coal-measures of Iowa in the one case, and in the Carboniferous Limestone of the same State in the other*.

In the Carboniferous rocks (Coal-measures and Lower Coal-measures) of Nova Scotia the following species are known to occur:—*Leperditia Okeni*, *L. scotoburdigalensis*, *L. acuta*, *Carbonia fabulina*, and *C. bairdioides* (?)†.

These are all the British Ostracods whose range is as yet known to extend to the American continent. Two of them (*Leperditia scotoburdigalensis* and *Carbonia fabulina*) were essentially estuarine forms. They are the commonest species of all in the Coal-measures and Calcareous Sandstones of the North British area; and their constant occurrence in shales, ironstones, and impure limestones (intercalated with coals), associated with the remains of plants, indicates that they were anything but of deep-sea habits.

§ 2. In Europe the following species have been described from Carboniferous strata in Russia:—*Leperditia Okeni*, *Kirkbya unbonata*, *Beyrichia colliculus*, *B. intermedia*, *Bairdia ampla*, *B. plebeia*, and *Bythocypris bilobata*; and *Kirkbya permiana* from the Permian strata of the same country‡.

Some of the best known of the British species were discovered by Count Münster in the Carboniferous Limestone of Bavaria; these include *Leperditia Okeni*, *L. oblonga*, *L. parallela*, *L. suborbiculata*, *Cytherella inflata*, *Bairdia Hisingeri*, *Bythocypris bilobata*, and *Cythere? intermedia* §.

In Belgium, as might be expected from its comparative nearness to Britain, several species occur that are included in this list. This more particularly applies to the Cypridinidæ ||.

Leperditia Okeni seems to have had the greatest geographical range, being found as far east as the Russian province of Toula, and as far west as Nova Scotia.

VII. APPENDIX.

1. BEYRICHIOPSIS, gen. nov.

Valves shaped and lobed much like those of some *Beyrichiæ*, but bearing longitudinal riblets, as in some *Kirkbyæ*. One of these ribs forms a dorsal crest; there is also a denticulate, spinose, or delicate fringe along the free margin. These characteristic features are well seen in *Beyrichiopsis fimbriata*.

* Monogr. Carbonif. Bivalved Entom., Palæont. Soc. 1884, pp. 77-79.

† Geol. Mag. dec. iii. vol. i. 1884, p. 356.

‡ Ann. & Mag. Nat. Hist. ser. 4, vol. xv. 1875, p. 52; and 'Lethæa Rossica,' 1860, vii. p. 1347.

§ Ann. & Mag. Nat. Hist. ser. 3, vol. xv. 1865, p. 406.

|| Monogr. Carb. Biv. Entom., Pal. Soc. 1874, pp. 32, 38, 40.

Scotland, and in the Permian

NORTH OF ENGLAND.

a permiana, *Macrocypris Jonesiana*, *Bairdia plebeia*, *B. ampla*, *B. acuta*, *Cythere* (?) *Morrisiana*, &c.

na primæva, *Macr. Jonesiana*, *Bairdia plebeia*, *B. Hisingeri*, *aputata*, *B. acuta*, *B. Kingii*, *Cythere* ? *Geinitziana*, *C. ? inter-*, *Cytherella nuciformis*, &c.

niana, *M. Jonesiana*, *B. plebeia*, *B. ampla*, *B. Hisingeri*, &c.

is of reptiles, fishes, and plants; no Ostracoda.

tia inflata, *Beyrichia subarcuata*.

ia arcuata, *Carbonia fabulina*, *C. Rankiniana*, *C. secans*, *alpellus*, *C. Wardiana*.

ia arcuata, *Carbonia* ? sp.

eni, *Beyrichia bituberculata*, *B. ventricornis*, *K. permiana*, *K. umbonata*, *K. spinosa*, *Cytherella scrobiculata*, *C. recta*, *Benniei*, *Bythocypris bilobata*, *B. carbonica*, *Cythere* ? *cornigera*, *luneola*, *Bairdia plebeia*, *B. ampla*, *B. brevis*, *B. submucronata*, *Hisingeri*, &c.

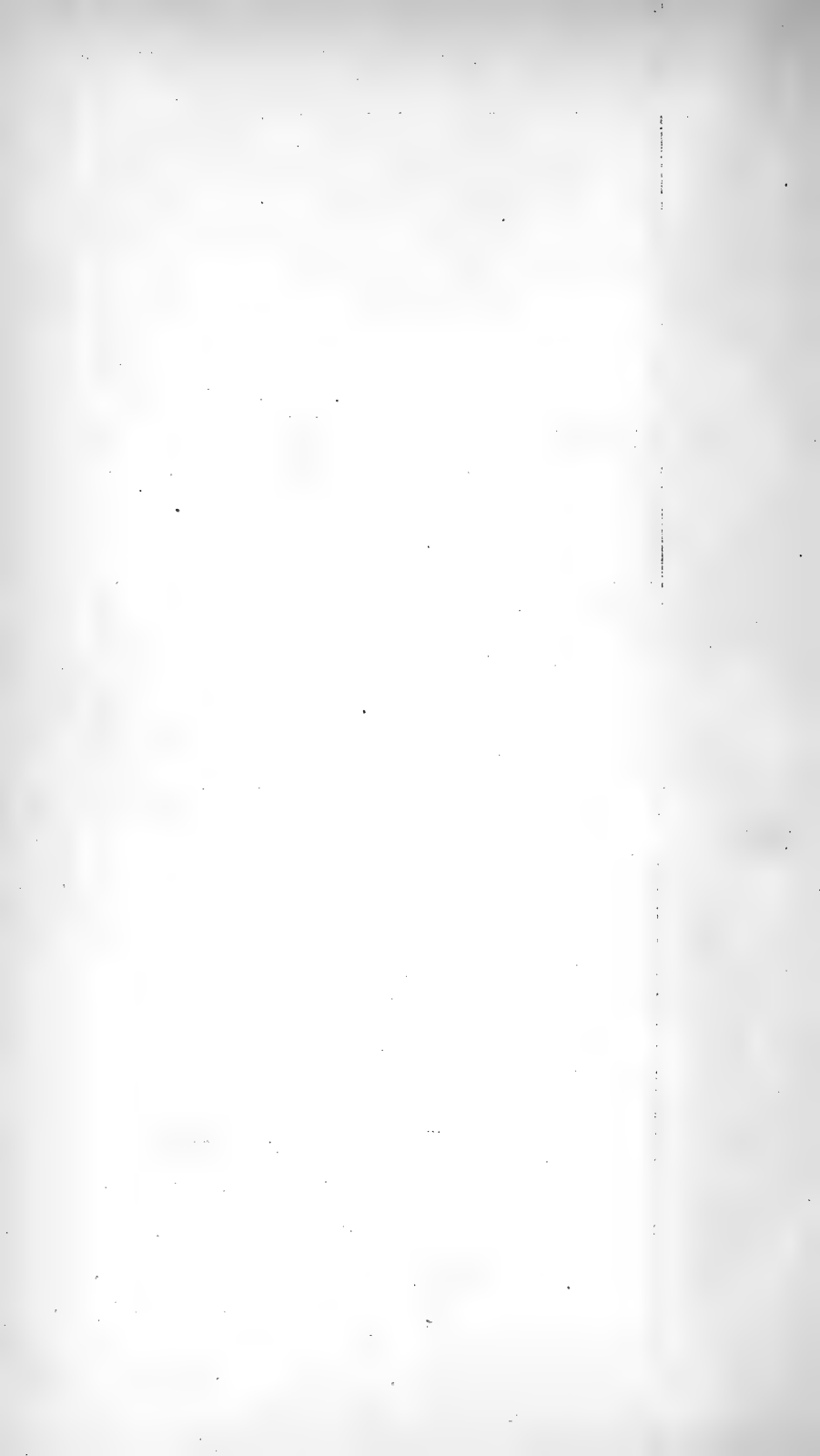
litia Okeni, *L. lovicensis*, *Beyrichia radiata*, *B. craterigera*, *B. reulospinosa*, *Kirkbya umbonata*, *K. costata*, *Bythocypris bilobata*, *Cytherella valida*, *C. Benniei*, *Bythocythere antiqua*, *Cythere* ? *ola*, *C. ? thraso*, *Bairdia curta*, *B. plebeia*, *B. ampla*, *B. amputata*, *B. grandis*, *B. submucronata*, *B. subelongata*, *B. brevis*, &c.

eni, *L. Armstrongiana*, *K. permiana*, *Bythocypris bilobata*, *dia amputata*, *B. brevis*, *B. Hisingeri*, *Xestoleberis* ? *subcorbulata*, &c.

eni, *L. suborbiculata*, *L. scotoburdigalensis*, *L. subrecta*, *Beyrichia rigera*, *B. ? crinita*, *B. radiata*, *Beyrichiopsis subdentata*, *B. firmata*, *K. costata*, *K. spiralis*, *K. umbonata*, *Cytherella valida*, *C. scrobiculata*, *C. extuberata*, *Argilloecia aequalis*, *Macrocypris Jonesiana*, *Bairdia Hisingeri*, *B. curta*, *B. plebeia*, *B. submucronata*, *B. subelongata*, *Bernix Tatei*, and others.

TABLE I.—Showing the Stratigraphical Distribution of the Ostracoda in the Carboniferous Series of Scotland, and in the Permian and Carboniferous Series of the North of England.

SCOTLAND.		THE NORTH OF ENGLAND.	
		MAGNESIAN LIMESTONE.	COAL-MEASURES.
		Upper { Kirkbya permiana, Macrocypris Jonesiana, Bairdia plebeia, B. ampla, B. acuta, Cythere (?) Morrisiana, &c. Middle { Cypridina primæva, Macr. Jonesiana, Bairdia plebeia, B. Hisingeri, B. amputata, B. acuta, B. Kingii, Cythere ? Geinitziana, C. ? intermedia, Cytherella nuciformis, &c. Lower..... { K. permiana, M. Jonesiana, B. plebeia, B. ampla, B. Hisingeri, &c. Marl-slate..... { Remains of reptiles, fishes, and plants; no Ostracoda. Lower Red Sandstone ...	
COAL-MEASURES.	Upper Red beds { Carbonia fabulina, C. Rankiniana, C. secans, with Leacia Leidy. Group with workable coals { Cypridina radiata, Carbonia fabulina, C. Rankiniana, C. pungens, Beyrichia arcuata.		Upper { Leperditia inflata, Beyrichia subarcuata. Middle { Beyrichia arcuata, Carbonia fabulina, C. Rankiniana, C. secans, C. scalpellus, C. Wardiana. Lower { Beyrichia arcuata, Carbonia ? sp.
MILLSTONE GRIT.		MILLSTONE GRIT.	
CARBONIFEROUS LIMESTONE SERIES.	Upper group with limestones..... { Lep. Okeni, L. suborbiculata, Beyr. radiata, B. multi'oba, B. bituberculata, B. ventricornis, Kirkbya permiana, K. Urei, K. rigida, Bairdia plebeia, B. Hisingeri, B. curta, B. siliquoides, Cythere ? cuneola, C. ? cornigera, Cytherella recta, C. æqualis, C. scrobiculata, &c. Middle group: "Lower coals and ironstones." { Carbonia fabulina, C. Rankiniana, Leperditia Youngiana, Beyrichia sp. Lower group with limestones..... { Cypridina primæva, C. Phillipsiana, Polycpe simplex, P. Youngiana, Lep. Okeni, L. Armstrongiana, L. suborbiculata, Beyrichia radiata, B. multiloba, B. fastigiata, B. bituberculata, B. ventricornis, Kirkbya permiana, K. umbonata, K. Urei, K. oblonga, K. spinosa, Cytherella Benniei, C. recta, C. brevis, C. scrobiculata, C. simplex, Bythocypris bilobata, B. carbonica, Cythere ? cuneola, C. ? cornigera, Bairdia plebeia, B. curta, B. Hisingeri, B. brevis, B. ampla, B. submucronata, B. subelongata.		YOREDALE ROCKS { L. Okeni, Beyrichia bituberculata, B. ventricornis, K. permiana, K. Urei, K. umbonata, K. spinosa, Cytherella scrobiculata, C. recta, C. Benniei, Bythocypris bilobata, B. carbonica, Cythere ? cornigera, C. ? cuneola, Bairdia plebeia, B. ampla, B. brevis, B. submucronata, B. Hisingeri, &c. Leperditia Okeni, L. lovicensis, Beyrichia radiata, B. craterigera, B. tuberculospinosa, Kirkbya umbonata, K. costata, Bythocypris bilobata, Cytherella valida, C. Benniei, Bythocythere antiqua, Cythere ? cuneola, C. ? thraso, Bairdia curta, B. plebeia, B. ampla, B. amputata, B. grandis, B. submucronata, B. subelongata, B. brevis, &c.
CARBONIFEROUS SANDSTONE SERIES.	Cement-stone group { Lep. Okeni, Beyr. radiata, Kirkbya permiana, Bairdia plebeia, Carbonia fabulina, C. Rankiniana, Lep. scotoburdigalensis. Lep. Okeni, Beyr. radiata, Cythere ? sp., Bairdia plebeia, B. Hisingeri, B. amputata, B. brevis, B. subelongata, Cythere ? sp. Carbonia Rankiniana, C. subula. Lep. Okeni, Kirkbya spiralis. Lep. scotoburdigalensis. Beyrichiopsis fimbriata, Leperditia Okeni, Bairdia sp., Cytherella sp. Lep. scotoburdigalensis, Beyr. subarcuata, Cythere ? superba, Cytherella extuberata, Kirkbya spiralis. L. Okeni, L. scoto., Beyr. subarcuata, B. sp., K. spiralis, K. plicata, Cytherella extuberata, C. attenuata, Bairdia plebeia, B. Hisingeri, B. siliquoides, B. præcisa, Macrocypris Jonesiana, Argillœcia æqualis. Beyrichia subarcuata, Carbonia fabulina, C. Rankiniana.		CARBONIFEROUS OR SCAR LIMESTONE { L. Okeni, L. Armstrongiana, K. permiana, Bythocypris bilobata, Bairdia amputata, B. brevis, B. Hisingeri, Xestoleberis ? subcorbuloides, &c. L. Okeni, L. suborbiculata, L. scotoburdigalensis, L. subrecta, Beyr. craterigera, B. ? crinita, B. radiata, Beyrichiopsis subdentata, B. fimbriata, K. costata, K. spiralis, K. umbonata, Cytherella valida, C. scrobiculata, C. extuberata, Argillœcia æqualis, Macrocypris Jonesiana, Bairdia Hisingeri, B. curta, B. plebeia, B. submucronata, B. subelongata, Bernix Tatei, and others.
	Cornstone or Red Sandstone group { Leperditia subrecta, L. Okeni.		LOWER LIMESTONE-SHALF.



2. PHREATURA *, gen. nov.

Valves small, subreniform in outline; seen from above or below the carapace is subcuneiform, pointed in front, truncate behind. Left valve the largest, and overlapping the other nearly all round. The surface of the valves smooth, but impressed at each end with a comparatively large and deep pit; hence the name. The only species yet known, namely, *Phreatura concinna*, J. & K., is about $\frac{1}{40}$ inch long, and is very neat in shape. This genus approaches the Silurian *Thlipsura*.

3. YOUNGIA, gen. nov.

Minute, elongate, subrectangular, thick-shelled, and smooth, with a straight dorsal border that has the contact-surface of the hinge-margin denticulated along its whole length, after the manner of *Arca*.

Only one species (*Y. rectidorsalis*, J. & K.) of this genus is as yet known to us, and it was discovered by our friend Mr. John Young, of Glasgow, with whose name we associate the genus. The discovery of additional species may probably add to the generic characters. The chief feature of the genus, as now known to us, is its toothed hingement, which is certainly unique among the Carboniferous Entomostraca, though partially represented in *Cytheridea* among later forms.

NOTE.—Since this paper was read many of the species here mentioned have been described and figured in the *Annals & Mag. Nat. Hist.* for October 1886, and the *Geological Magazine* of the same date. Others in the *Proceedings of the Geologists' Association*, vol. ix. part 7. With them also the following new species have been described and have to be added to the following lists and Table, namely:—

Cythere? obtusa, J. & K. Yoredale series; Lowick, Northumberland. *Ann. & Mag. Nat. Hist.* October, 1886, p. 266, pl. ix. fig. 12.

Beyrichiopsis cornuta, J. & K. Carboniferous Limestone series; Linlithgowshire, Fifeshire, and Northumberland. *Geol. Mag.* Oct. 1886, p. 436, pl. xi. fig. 11.

Beyrichiella cristata, J. & K. Calciferous Sandstone series; Randerstone, Fife. *Geol. Mag.* Oct. 1886, p. 438, pl. xii. fig. 6.

We may add that *Cythere? cuneola*, *cornigera*, *pyrula*, and *thraso* are now referred to *Bythocypris* with some doubt; and *C.? lunata* more decidedly to that genus. *Beyrichia Holliana* may be a *Primitia*; and *B. reticosa* and *ventricornis* probably belong to *Beyrichiella*. *Bairdia subcylindrica?* (Münster) should have been entered under sp. 146 as belonging to the Lower Carboniferous of East Scotland (p. 500).

* From φρέαρ(-aros), a well or pit, and οὐρά, a tail.

TABLE II.—The Genera and Species of Carboniferous Ostracoda, and their Occurrences in England, Scotland, and Ireland.

	ENGLAND, SOUTH.		ENGLAND, NORTH.			SCOTLAND, EAST.				SCOTLAND, WEST.				IRELAND.	EUROPE.
	Carboniferous Limestone.	Coal-measures.	Carboniferous Limestone.	Yoredale Rocks.	Coal-measures.	Califerous Sandstone.	Lower.	Middle.	Upper.	Coal-measures.	Lower.	Middle.	Upper.			Coal-measures.
1.
2.	..	?
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.

Cypridina primæva (M. Coy)
radiata, Jones, Kirkby, & Brady
Wrightiana, J., K., & B.
Bradyana, Jones & Kirkby
brevimentum, J., K., & B.
Youngiana, J., K., & B.
Hunteriana, J., K., & B.
pruniformis, J., K., & B.
oblonga, J., K., & B.
Grossartiana, J. & K.
Phillipsiana, Jones
Thomsoniana, J. & K.
scoriacea, J. & K.
Cypridinella Cummingii, J., K., & B.
superciliosa, J., K., & B.
clausa, J., K., & B.
[*Bosqueti*, J., K., & B. Belgium.]
Maccoyiana, J., K., & B.
monitor, J., K., & B.
vomer, J., K., & B.
Cypridellina clausa, J., K., & B.
Burrovii, J., K., & B.
—, var. *longnoriensis*, J., K., & B.

TABLE II. (continued).

	ENGLAND, SOUTH.		ENGLAND, NORTH.			SCOTLAND, EAST.				SCOTLAND, WEST.				IRELAND.	EUROPE.	
	Carboniferous Limestone.	Coal-measures.	Carboniferous Limestone.	Yoredale Rocks.	Coal-measures.	Carboniferous Sandstone.	Lower.	Middle.	Upper.	Coal-measures.	Carboniferous Limestone Series.	Lower.	Middle.			Upper.	Coal-measures.
116.	*
117.	*
118.
119.	*
120.	*
121.	*
122.
123.
124.
125.
126.
127.
128.
129.
130.
131.
132.	*
133.
134.	*
135.
136.	*
137.
138.

Kirkbya spinosa, J. & K.
Urei, Jones
rigida, J. & K.
variabilis, J. & K.
Moorea tenuis, J. & K.
obesa, J. & K.
Carbonia fabulina, J. & K.
Rankiniana, J. & K.
subula, J. & K.
scalpellus, J. & K.
secans, J. & K.
pungens, J. & K.
Evelina, Jones
Agnes, Jones
? baardioides, J. & K.
Wardiana, J. & K.
Bythocypris bilobata (Minster)
Phillipsiana, Jones & Holl, var. carbonica, J. & K.
sublunata, J. & K.
Argilloecia aequalis, J. & K.
Macrocypris Jonesiana, Kirkby
carbonica, G. S. Brady
Aglaia cypridiformis, J. & K.

NOTE.—A few weeks ago Mr. J. Ward, F.G.S., of Longton, favoured us with a specimen of impure limestone from the Millstone Grit of Danebridge, Macclesfield, containing Ostracoda. Unfortunately the matrix is so refractory and the valves are so imperfectly preserved that we cannot in any case determine either the genus or species. Mr. J. Bennie informs us also that he has incidentally noticed Ostracods, in beds holding a Millstone-Grit position, in Scotland. So it is evident that fossils of this order exist in rocks of this Middle Carboniferous age, and that only additional search is required to bring them to light.—*October 18, 1886.*

DISCUSSION.

Dr. Woodward congratulated the Authors on their care and patience in working up the subject. Much of this work was done under considerable discouragement, since the siliceous examples in which the structure of the appendages is preserved are not available in this country, and without these authors are dependent solely on the examination of the characters presented by the carapaces. Mr. Brady, who had examined the specimens upon which Prof. Rupert Jones's observations were founded, was satisfied that the classification adopted by the author for the fossil Ostracoda was the best that the materials afforded.

42. *The GEOLOGY of CAPE BRETON ISLAND, NOVA SCOTIA.* By EDWIN GILPIN, Esq., Jun., A.M., F.R.S.C., Inspector H.M.'s Mines. (Read June 23, 1886.)

IN the following notes the writer has tried to give a brief account of the geology of this island from notes of his professional work as Inspector of Mines and from other available sources. Mr. R. Brown, of the Sydney mines, lived for many years on the island when it was, geologically speaking, an unexplored region. The Transactions of the Society contain several valuable papers of his, giving many details of the Carboniferous system. Sir J. W. Dawson, in his 'Acadian Geology,' indicated the outlines of the principal geological divisions, and devoted much attention to the Carboniferous flora. During the past fifteen years Mr. H. Fletcher, of the Canadian Geological Survey, has explored and mapped the island, and the map accompanying these notes has been reduced from the large scale-plans accompanying his annual reports, from which I have taken several sections. Valuable reports were made by Professor Lesley, Mr. Lyman, and others on several districts considered of economic importance; but the list of writers is a scanty one.

The geology of Cape Breton is notable on account of the development of two great rock series—the Carboniferous and the Pre-Cambrian. There are no measures known later than the upper portion of the productive Coal-Measures, and between the basal conglomerate of this period and the Pre-Cambrian there intervene only a few areas referred to the Devonian and the Lower Silurian.

The following formations have been recognized in Cape Breton by the officers of the Geological Survey:—

- PRE-CAMBRIAN (Laurentian):
 Including { The Felsite series,
 { The Crystalline Limestone series.
- LOWER SILURIAN.
 DEVONIAN.
 CARBONIFEROUS:
 Including { Middle Coal-formation,
 { Millstone Grit,
 { Gypsiferous series,
 { Limestones, &c.
 { Lower Coal-formation.

PRE-CAMBRIAN, FELSITE SERIES.

The exact age of the strata included under this term has been a matter of doubt, and many have called them Laurentian. Their isolated position has precluded the chance of following them into regions where convincing stratigraphical relations can be found. The auriferous rocks of the Atlantic coast of Nova Scotia do not extend into the island, but they supply an important link in the geological sequence. They are considered to be Lower Cambrian, the equivalents of the Longmynd series, and appear with the Acadian series of St. John, New Brunswick, to belong to the gap

between the Lower Silurian or Upper Cambrian of Cape Breton, to be alluded to as probable equivalents of the Lower Potsdam or Lingula Flags, and the series under consideration.

This formation occupies more than one half of the island. North of the Bras d'Or lake it stretches in a wide belt to Cape St. Lawrence, interrupted only by the Carboniferous of Margaree River and Lake Ainslie, and by narrow fringes of the same strata around the shore and along the valleys of some of the larger streams rising in the centre of the island. Other large areas are occupied by these strata at Cape Mabou, Washabak, Judiqué, Mira, Boisdale, Coxheath, and St. Anns, where they rise prominent among the low-lying hills and valleys of the Carboniferous.

Two divisions have been recognized in these measures. The lower consists of laminated felsites and of interstratified porphyry and syenitic* and gneissoid rocks; the upper is characterized by the addition of great beds of limestone. Mr. Fletcher, speaking of the lower division, gives it as the result of his experience that both the felsitic and syenitic strata are intimately associated as part of the same group of crystalline rocks, differing not so much in composition as in the degree of crystallization they have been subjected to, and that as no evidence has been found proving the higher position of the felsites, they may at present be considered together.

The Washabak hills consist of gneiss, mica-schist, syenite, diorite, hornblende rock, quartzite, and felsite; all are more or less foliated, and sometimes in exceedingly thin laminae. The Boisdale and Mirá hills are made up chiefly of obscurely bedded syenite, with limited areas of other rocks; the Coxheath hills of alternations of syenite, quartzite, and compact felsite; and the East Bay hills of felsite, syenite, and granite, in every gradation of colour and texture. In the Boisdale hills this series is represented principally by bluish and grey syenite. The syenite contains seams of a serpentinous mineral, and passes frequently into granite, quartzite, felsite, and a fine-grained porphyry, with interspaced flakes of hornblende, felspar, and mica.

In the districts of Gabarus and Louisberg felsites predominate, and at the former place include beds of felspathic sandstone. Possibly further examination may assign these rocks to a horizon higher than that represented by the East Bay section (to be given below), or they may prove to be later than the crystalline limestone series.

At Cape Porcupine, on the Strait of Canso, slates occur with coarse syenite, and felsites resembling those of Louisberg and Gabarus. In the Sporting Mountains the felsites occur with red syenite, whereas the Craignish mountains are composed principally of reddish syenite, overlain by the limestone series. In the northern part of the island the exposures of the great expanse of these rocks present the same general features. It may be assumed that a more minute and extended study must be devoted to this interesting series of measures before it can be decided what subdivisions, if any, can be determined on.

* The term "syenite" is applied by the Canadian Geological Survey to a mixture of quartz, soda or potash felspar, and hornblende.

The following section at Irish Cove, East Bay, may serve to convey a general idea of the character of these measures, and of the association of the felsites with the red and grey syenites:—

Greenish, white, and red laminated and granitoid felsite	ft. 480
Greenish felsite and red syenite	100
Bluish soft porphyry	85
Purple and bluish laminated felsite	233
Red syenite and reddish soft granitoid rock	247
Greenish and reddish granitoid rocks, often nearly pure felspar	269
Felsite and syenite of variable composition, with veins of calcite	130
Red granitoid felsite, with diorite	160
Similar alternations of red and greenish felsites and syenites make up a thickness of	3000
Red and grey syenite, coarse and fine	2333
Similar measures, composed of alternations of felsites, syenites, and aluminous nacreous shales, greenish and grey in colour, make up a section not less than 8900 feet in thickness.	

At numerous points throughout the island these measures are cut by dioritic dykes, some of which are as late as the Lower Carboniferous, but they have not yet been described in any detail.

CRYSTALLINE LIMESTONE SERIES.

Unconformably resting on these strata, but agreeing with them in their general development and position, is an interesting series of felsites, syenites, diorites, mica-schist, quartzite, and quartzose conglomerate, interstratified with crystalline limestone and dolomite. These measures are locally known as the George's River Limestones of St. Andrew's Channel, the locality in which they are typically developed and were first referred to their true position.

The alternation of the limestone with the gneissoid and related rocks brings them into close connection with the felspathic group, from which, however, they are apparently separated, owing to the presence of red syenite and felsite pebbles in the lower conglomerates and by unconformability. Similarly the Lower Silurian conglomerates of St. Andrew's Channel have received witnesses from this limestone series. However conjectural any speculation may be as to the age of these measures, it is certain that, as compared with the metamorphic slates and quartzites of the Lower Cambrian auriferous strata of Nova Scotia and the fossiliferous Lower Silurian of St. Andrew's Channel, they mark a line equal to that observable between the latter and the indurated Devonian and Carboniferous of this island.

The area occupied by this limestone series is limited in comparison with that of the felsite group, but it was formerly, in all probability, of much greater extent, for it presents at several points traces of having suffered severe denudation prior to the deposition of the Lower Silurian strata; and this is borne out by the thickness of the George River section, viz. 6602 feet.

In the northern district a narrow band stretches between Dundas and Ingonish rivers. Excepting a small patch on Middle River, it is not met with again until the head of Whyhogomah Bay is reached,

whence it stretches in a broad band for several miles, and its former further extent is marked by isolated patches as far as Cape Porcupine, on the Nova Scotian side of the Strait of Canso. The Malagawatch hills are flanked by a narrow fringe of the same series, known as the Marble Mountain. It is most typically developed on the Boisdale and Coxheath hills, where it extends, in a narrow and interrupted band, from Escasonie, on East Bay, to St. Andrew's Channel.

The following section from the last-named district will serve as an index to its general character in the localities alluded to:—

Compact granitoid felsite of many colours	ft. 74
Grey and greenish friable gneiss	23
Black and amber-coloured vitreous quartzite	115
White and grey syenite	140
Massive white vitreous quartzite	400
Bluish granitoid rock	3
Colourless laminated quartzite and red syenite	68
Greenish finely crystalline hornblende rock	141
Red syenite	8
White and bluish crystalline limestone	13
Red syenite	8
Greenish-grey granitoid felsite	29
White and bluish limestone and dolomite	8
Red syenite, felsite, and porphyry	7
Limestone, bluish and saccharoidal	16
Red syenite	2
White limestone and dolomite	378
Greenish fine-grained felsite	37
Greenish pyritous granite and felsite	112
Granitoid rock	18
Red syenite	37
Granite, quartzite, and bluish felsite	473
White, bluish, and grey quartz, bluish granite, and red syenite .	3794

The above, with some concealed intervals, make up a thickness of 6602 feet.

These strata resemble in many points the Limestone series overlying the syenitic and felsitic group of Newfoundland and New Brunswick, and form the principal argument in favour of referring both series to the Laurentian. Mineralogically there is also a resemblance, for in Cape Breton, asbestos, mica, plumbago, and bedded iron-ores are frequently met among the limestone series, and the discovery of apatite would render the comparison with the Quebec Laurentian limestone complete.

LOWER SILURIAN.

The area of this formation is limited. Its principal exposure extends along the southern side of the Mira River for about 30 miles, and has an average width of about 7 miles. A narrow, irregular band stretches from Escasonie, on East Bay, nearly to the mouth of the St. George's River, its width, however, never exceeds one mile. A small patch is also exposed at Shenacadie, on the Little Bras d'Or Lake.

The thickness of these measures has not been determined, as they

are greatly folded and repeated by faults. They are distinguished by numerous beds of conglomerate, and of fine and coarse grits, plainly derived from the Pre-Cambrian strata. At numerous points are found beds filled with species of *Lingula*, Trilobites (*Agnostus* and *Olenus*), *Orthis*, *Obolella*, &c., comparable with the fossils of the Lower Potsdam of the province of Quebec. At several points there are beds containing nodules of phosphate of lime, resolvable under the microscope into a bituminous paste holding siliceous matter and fragments of *Lingule* &c.,—coprolites, presumably of some of the larger species of Trilobites. Mr. Fletcher further draws attention to the general similarity of these measures to the primordial rocks of Newfoundland, and to those found by Mr. Richardson on the Strait of Belleisle. The following abstract of the section of these rocks, as exposed on Long Island, will show their general character in St. Andrew's Channel:—

1. Greenish-grey, coarse, calcareous conglomerate, containing red syenite, felsites, and quartzites of many colours, interstratified with coarse, micaceous, hæmatitic sandstones, and blue, purple, and red felsites.
2. Bluish, slaty felsite, with much calcspar and hæmatite.
3. Greenish, calcareous, pebbly and shaly sandstones.
4. Dark blue, greenish, and red felsites, with pebbles and veins of calcspar.
5. Sea-green and bluish conglomerates, with pebbles of felsite, calcspar, quartzite, and argillite.
6. Bluish felsite, with much calcspar.
7. Bluish limestone.
8. Red conglomerate.
9. Bluish limestone, felsite, and contorted argillite, with veins of hæmatite and calcspar.
10. Bluish quartzose grit, passing into a red conglomerate.
11. Limestone and felsite alternating in thin beds.
12. Bluish-grey felspathic sandstone.
13. Alternations of felsite, limestone, quartzite, and argillite.
14. Indian red sandy marl, with calcareous sandstone.
15. Bluish felsite, with beds of limestone and quartzite.

In the Mira River district, on the Sydney road, are met greenish, purple and reddish, soft, felspathic, micaceous, arenaceous shales and sandstones, quartzite, grit, and conglomerate, with pebbles of limestone and greenish argillite. On Kelvin's Brook are conglomerates containing pebbles of the Pre-Cambrian Measures, succeeded by purple, grey, and red quartzose and felspathic sandstone and grit, and by Indian red argillites; and on Salmon River are beds of whitish sandstone, with impressions of *Obolella*, &c., with red sandstone, marl, conglomerate, &c. It may be remarked that these measures are, as a rule, free from the eruptive rocks which characterize the succeeding formation at many points.

DEVONIAN.

These measures occupy an irregular tract, extending from Loch Lomond to St. Peters, and reappear in Isle Madame. They are met with again in that part of Guysboro Co., in Nova Scotia proper, lying between Chebucto Bay and the Strait of Canso, and, recrossing the Strait, extend irregularly from Plaster Cove towards the head waters

of River Inhabitants. The available evidence points to the Devonian age of these measures, as laid down by Mr. Fletcher; but Sir J. W. Dawson is inclined to refer part, at least, to the Silurian. Further search may provide more fossil evidence, although, as Mr. Fletcher remarks, the rocks consist generally of shallow-water deposits.

The unconformability between this formation and the preceding is much more marked than between it and the Carboniferous; but the unconformable junctions with the latter are strongly marked at Arichat, Lennox Passage, and Guysboro Harbour by degrees of metamorphism, included pebbles, and stratigraphical position. The total thickness of the formation has not been ascertained, but the dimensions of various sections would corroborate that of Lennox Passage, where a vertical thickness of 10,000 feet has been measured.

The measures, as described by Mr. Fletcher, are arenaceous, argillaceous, and nacreous shales and sandstones, passing into grits of grey, red, and purplish shades, with beds of conglomerate holding quartzite and felsite pebbles. Limestones are met with at several points, and, as at St. Peters, Pirates' Cove, &c., appear to mark an upper horizon. At numerous localities masses of diorite and trap are protruded among these measures. This is especially noticeable in the vicinity of St. Peter's Canal. The canal itself is cut in a rock consisting essentially of a greenish-grey and bluish mixture of hornblende and felspars, intersected by veins of quartz and felspar. In the Indian Reserve, in the same district, the sedimentary rocks are broken through by grey and greenish compact and granular diorite, and pyritous epidotic felsite, traversed by veins of calcespar. At Jerome Point &c. are found exposures of black, greenish, and purplish compact or granular, rusty-weathering trap, which is sometimes porphyritic or globular, and charged with zeolites, hæmatite, and chlorite. At several points near St. Peter's and Guysboro, important deposits of specular ore are met with, apparently associated with these eruptive rocks.

CARBONIFEROUS.

This formation is conspicuously developed in Cape Breton; and, apart from the fisheries, to its coal and fertile limestone and gypsum soils are due what measure of prosperity the island enjoys. Sir J. W. Dawson, in his 'Acadian Geology,' has arranged the Carboniferous of the Lower Provinces in the following subordinate formations:—

1. *The Upper Coal Formation*, containing coal-formation plants, but only thin coal-seams.
2. *The Middle or Productive Coal Formation.*
3. *The Millstone Grit.*
4. *The Carboniferous Limestone*, with marls, gypsum, &c.
5. *The Lower Coal-measures*, holding some of the middle coal-formation fossils and thin coal-beds.

Some districts do not present all these divisions, the lowest one being frequently wanting or sparingly represented. And in many

cases no divisional line can be drawn separating the Millstone Grit in its passage upwards from the Productive Measures, or downwards from the limestone series. The most instructive section is that at the Joggins, in Cumberland county, Nova Scotia, where all the subordinate formations are fully developed.

In several cases in Cape Breton the gradual passage of the subdivisions is strongly marked. In this island the arrangement of this formation is that of valleys between the ridges of the Pre-Cambrian hills, and their softer strata have been worn into broad river-valleys and rolling hills of inconsiderable altitude. When they rest on the flanks of the older hills, they present picturesque and charming gorges, worn by the brooks, which are long fed by the accumulated winter snows.

As the eastern district is the most typically developed, a brief description of it will answer for the central and northern ones, which resemble it in the physical characters of the rocks, and differ from it chiefly in the correlation of the subdivisions.

In the Sydney, or eastern district, as in the remainder of the island, the upper division is wanting, unless represented by a few beds at Low Point, and some of the upper beds of the River-Inhabitants district. The shore, from Cape Dauphin to Mira Bay, is occupied by the Productive or Middle Coal-measures, which are folded in three undulations having an east and west axis, corresponding to that of the Pre-Cambrian strata. As the measures are interrupted at the anticlines, the exact identification of all the seams is doubtful.

The following section in the Lingan district, in the centre of the field, will serve to show the relative thickness of the strata and of the included beds of coal:—

	ft.	in.
Seam A.....	3	0
Strata ..	306	2
Carr seam.....	6	5
Strata ..	191	0
Barasois seam ..	12	0
Strata ..	379	3
David Head seam ..	8	0
Strata ..	235	0
Seam D.....	3	0
Strata ..	78	0
North Head seam ..	4	0
Strata ..	76	0
Lingan Main seam ..	8	0
Strata ..	95	3
Seam G.....	2	6
Strata ..	340	5
Seam H.....	1	0

This section does not embrace lower coal-seams of workable dimensions included in the Millstone Grit of the Geological Survey.

Shales, arenaceous and argillaceous, with red and green marls, make up one half of the strata. The shales pass into sandstones, and frequently carry ironstone nodules; and the more argillaceous beds are crowded with fossils, chiefly ferns. Many trunks of erect

and prostrate *Sigillariae*, with roots attached and growing into the coal, are seen in these shales. Trunks have been observed nearly five feet in diameter, but they do not usually exceed two feet. The term "marl" is here applied, not to beds necessarily calcareous, but to red and green shales which crumble on exposure. Sandstone-beds, grey and white in colour, and often fifty feet in thickness, are met at frequent intervals, and nearly always occur a few feet above the coal-beds. Many of the beds are calcareous, and are then flaggy, micaceous, and sometimes ripple-marked. Almost invariably underclays, highly charged with roots and rootlets, occur under the coal-beds, but in a few cases the coal-seams rest directly on thin beds of fossiliferous limestone, and, in one case, the floor is sandstone. The coal-beds do not merit any particular notice, being similar in many points to those of the Durham coal-field.

MILLSTONE GRIT.

The division-line between this formation and the Productive Measures is entirely an arbitrary one, and, as marked on the Geological Survey maps, is regarded by many as encroaching on measures that may fairly, so far as their coal contents are concerned, be considered productive. This is borne out by the fact that a collection of fossil plants, from a point apparently low down in this horizon, about two miles east of Sydney, shows species, according to Sir J. W. Dawson, occurring only in the Productive Measures, and especially in its higher beds.

As compared with the higher division, these strata show a much larger percentage of sandstones, frequently coarse and sometimes felspathic, fewer argillaceous beds, and much false stratification; and this formation is specially distinguished from those lying above and below it by the absence of calcareous matter. Near the old syenitic and felsitic rocks the prevailing colour is red; further away, where the material has been derived from the preceding Carboniferous horizons, grey shales are met with. The maximum thickness in this district is 5700 feet, but it rapidly diminishes towards the north, until at Cape Dauphin only 500 feet are found. Numerous coal-seams are met, some of workable size and persistent for long distances. The long arm of Millstone Grit, extending up the Salmon and Gaspereau rivers, contains several thin seams of coal, and may represent the formation as developed east of Sydney.

THE CARBONIFEROUS LIMESTONE.

In the Sydney district this formation occupies a triangular tract of country between the two arms of Sydney Harbour, and attains a thickness of about 2000 feet. It is composed principally of red and grey shales, sometimes approaching marls in aggregation, argillaceous and calcareous, and frequently carrying nodules of ironstone and limestone. Numerous beds of limestone are met, compact, laminated, or concretionary, usually grey and blue in colour, but sometimes black and bituminous; these are frequently associated with beds of gypsum and anhydrite, in some parts of the island over

200 feet in thickness. Beds of red and grey sandstone, usually laminated, often micaceous and ripple-marked, are frequently met with. The limestones generally contain the fossils characterizing this horizon, and are frequently charged with galena and copper pyrites, celestine and manganese ores.

The following section, from the 'Geological Survey Report,' 1875-76, p. 407, gives a good idea of the conditions under which the gypsum and limestone are usually presented:—

	ft.	in.
Bluish-grey columnar limestone	136	0
Green marl.....	9	0
Black bituminous nodular limestone, mottled greenish and red compact limestone... ..	55	0
Gray, compact, green, and mottled limestone	40	0
White crumbling gypsum	15	0
Green gypseous marl	0	7
Pink gypsum	0	0 $\frac{1}{2}$
Greenish gypseous marl	0	10
Pink gypsum and greenish marl	0	6
Red micaceous marl with gypsum	7	0
White gypsum	1	0
White gypsum and marl, with veins of gypsum	1	6
Nodular gypsum, marl, and limestone	4	0

The gypsum varies greatly, and the following description of an immense cliff, over one hundred feet in height, on the Bras d'Or Lake, will serve to show its characteristic features. It is essentially white, but spotted and tinted with many colours. It lies in beds often massive, but frequently pointed in every direction. It is usually compact, but often granular, minutely crystalline, or fibrous and radiating. Crystals of selenite, of a brownish colour, frequently occur in it; they are isolated or arranged in radiating groups, and sometimes give the rock a porphyritic appearance. The rock is frequently traversed by veins filled with fibrous gypsum of various colours, or with large plates of transparent selenite. Layers and nodules of anhydrite and of limestone frequently occur in the beds or divide them. Long-continued weathering roughens the surface of the gypsum, owing to the presence of silica as sand. Glauber's salt, common salt, and carbonates of magnesia and calcium, sulphur, and several varieties of silico-borate minerals are not uncommon.

LOWER COAL-MEASURES.

(*Lower Carboniferous Conglomerate.*)

This, the lowest member of the Carboniferous division, corresponding with the Bonaventure formation of Gaspé, and the basal conglomerate of New Brunswick and Newfoundland, is of variable volume, and cannot in this district be separated by any strict line from the overlying limestone formation; and it is the opinion of Mr. Fletcher that, in the districts surrounding the Bras d'Or Lake, much of it may be considered contemporaneous with the Limestone series.

In the Sydney district, near the Coxheath Hills, it has a thickness of 2525 feet, which rapidly diminishes as its strike is followed

to the north and south. This formation generally presents the aspect of a friable, reddish conglomerate, the pebbles varying in size up to a diameter of three feet. The masses are frequently of little coherence; in some cases the matrix is calcspar, hæmatite, or quartz. The conglomerates, the distinguishing feature of the formation, alternate with beds and masses of red and grey, coarse- and fine-grained, friable sandstones, and with beds of red and green marl and an occasional bed of limestone. Usually the upper beds are finer than those at the base, but many sections are largely made up of conglomerates.

Passing to the westward we meet the Carboniferous of St. Peter's Bay and the River Inhabitants. The marine limestone and some representatives of the division just alluded to border St. Peter's Bay and inlet and the northern shore of Isle Madame, and, passing under the higher divisions, skirt the Sporting Mountains, and passing round the head of West Bay, fill the valley of the River Inhabitants, and are exposed on the shore of the Strait of Canso at Plaster Cove. In this group are included measures which resemble more closely the typical Lower Coal-formation of Sir J. W. Dawson's 'Acadian Geology' than any met elsewhere in the island, and the tint on the map really includes both the marine limestone and the lowest division. These measures pass into the River Denny's basin and extend to the Grand Narrows.

The officers of the Canadian Geological Survey have grouped the Carboniferous measures overlying these subdivisions under the term "Middle" Carboniferous, including the Millstone Grit, Productive Measures, and beds referred with doubt to the Upper Coal-formation, as the dividing lines are obscure and the structure not yet fully worked out. On the map the Middle Coal-formation districts, as indicated by coal-crops, are marked by their appropriate tint, and the remainder of the debatable ground is referred to the Millstone Grit. Mr. Fletcher gives the total thickness of the Carboniferous strata at 21,960 feet, which probably embraces all the subdivisions already described in the Sydney district; and, possibly, the 1350 feet of measures referred to by him as overlying the Little-River coal-series (8926 feet thick) may represent part of the Upper Coal-formation, subdivision No. 1 of Sir J. W. Dawson. The measures do not present many points of interest calling for special mention. It may be remarked that the coal-beds and their extent are imperfectly known, and that they are not considered so valuable as those met elsewhere in the island. Some of the sandstones and shales of the River Inhabitants are little more than compact sand and mud, while at other points the rocks have the normal hardness of the Carboniferous strata. *

In describing the Carboniferous strata lying north of a line drawn from Baddeck through Whyhogomah Bay to Low Point, Mr. Fletcher has adopted the following classification:—

Carboniferous { Middle: Millstone Grit and Middle Coal-formation,
 Lower: Conglomerate and Marine Limestone;

but I have followed the regular classification on the map.

The Coal-measures now form patches of what was, in all probability at one time, a continuous outcrop from Judique to Cheticamp. These strata resemble those described in the Sydney district, and contain numerous beds of coal of excellent quality, which, however, have not yet been worked. The Port Hood coals, in their high contents of water, from 3 to 7 per cent., resemble lignite coals, but in all other respects are excellent bituminous coals. The Millstone Grit of this district appears to be limited in extent, and may be represented by some of the strata underlying the coal-beds of Port Hood.

The line between these strata and the Marine Limestone is sharply marked by unconformability and the change in the conditions of deposition. The general characteristics of this subdivision are similar to those already noted, and its distribution may be learned from the map.

Underlying the Limestone series are numerous wide-spread areas of grits, coarse sandstones, and conglomerates, with argillaceous shales and a few beds of limestone. At Judique, Mabou, Broad Cove, Forest Glen, Grand Etang, and Cheticamp these Measures are greatly altered by the intrusion of igneous rocks. In the Judique district these intrusive masses vary greatly in texture, colour, and composition, but are essentially dark, massive, granular, and compact, chloritic, dioritic, and felsitic rocks. At many places little change has been produced in the sedimentary rocks at the point of contact, but frequently the metamorphism has been so great that no line of contact can be observed. At other points these strata are comparatively unaltered, and at Hunter's Mountain, Whyhogomah, and Lake Ainslie they hold bituminous shales with impure coal-beds, show signs of petroleum, and resemble the Lower Coal-Measures of Plaster Cove.

SUPERFICIAL GEOLOGY.

The superficial geology of Cape Breton does not present many points of interest. There are, I believe, no moraines to mark glacial action. The earth-covering varies according to the age and nature of the underlying strata. The Pre-Cambrian rocks are frequently almost bare, and their rugged and steep hill-sides afford soil only for the growth of timber; and rains following forest-fires have frequently denuded large tracts of almost every trace of earth. The more level tracts of the Pre-Cambrian, Silurian, and Devonian measures are diversified by numerous lakes, with slow streams and swamps. The soil is usually thin, clayey, or sandy, with boulders of the subjacent rocks. In the brooks and intervals sands and gravels are met with of recent derivation from the adjacent hills.

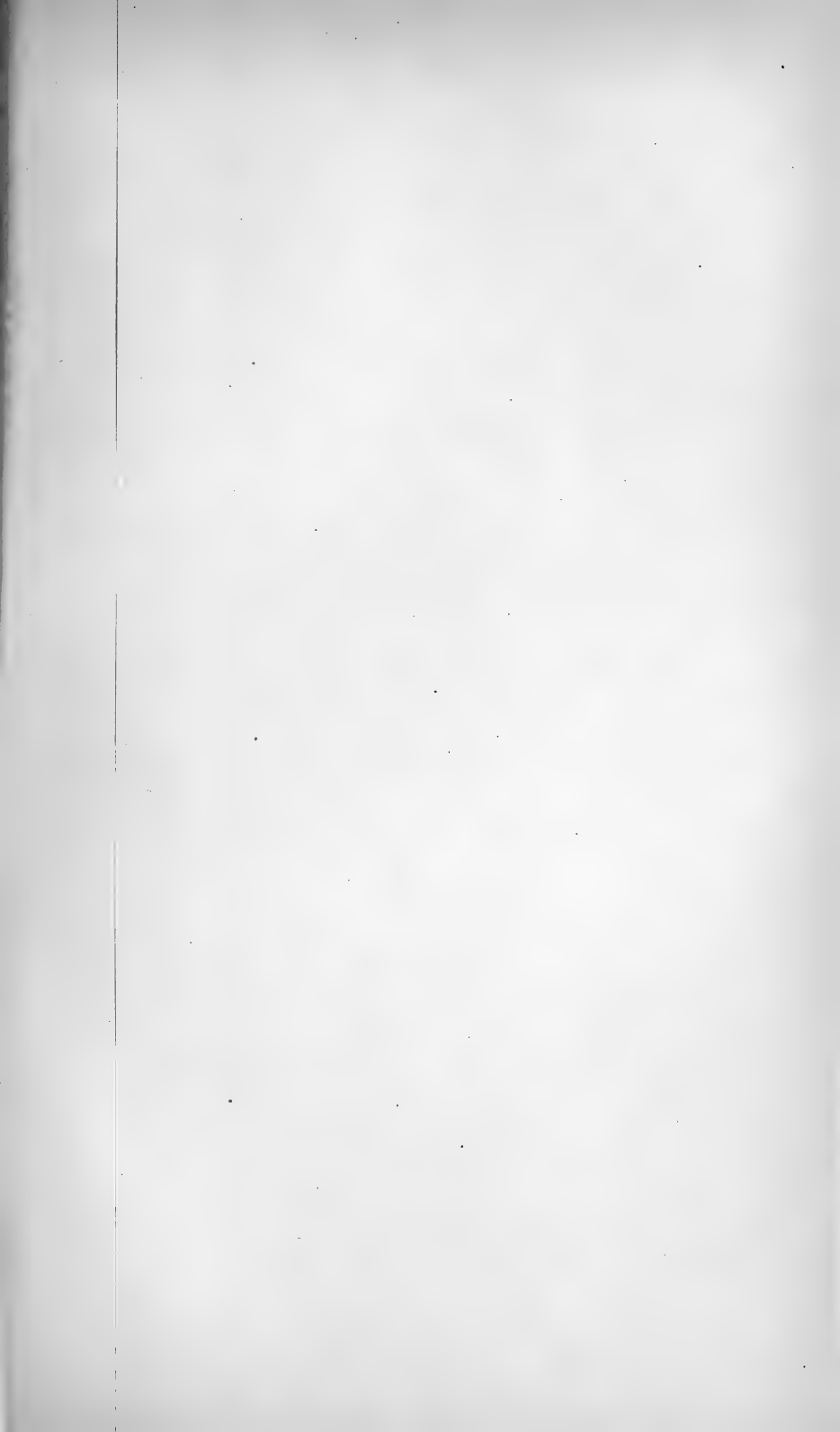
In the Carboniferous districts the soils are deeper and often of great fertility. The erratic boulders found over these measures are derived from the neighbouring subdivisions of the felsitic and syenitic series, and have seldom travelled far. In several localities peat and carbonized tree-trunks have been found under these clays, with remains apparently of *Mastodon giganteus* (?). There is a total

absence in Cape Breton of the fossiliferous marine clay characterizing the Post-Pliocene clays of the Lower St. Lawrence, and this may be due to rapid elevation of the land. At present it is thought by some that a slow subsidence is taking place.

The Carboniferous measures of the Sydney district have suffered greatly by the action of the ocean, which is rapidly wearing them away. At some points, according to Mr. R. Brown, the shore recedes at an average rate of five inches per annum. This waste of the softer measures has furnished material for the sand-beaches which are numerous around the Bras d'Or Lake and along the south coast of the island. The older rocks are often rounded, but seldom show striæ. Around Sydney Harbour and to the east and south of Sydney the striæ are observed chiefly on the Millstone Grit, and vary between S. 45° W. and S. 78° W. magnetic. Similar courses are met with at East Bay, Gabarus Bay, Framboise, and other points on the south shore.

It is perhaps probable that the courses of the compact ridges of the Pre-Cambrian strata have determined much of the denudation, and that the Bras d'Or Lake and the principal river-valleys owe their form to the cutting-out of the softer shales and sandstones, which are now frequently presented as fringing the harder and older measures.

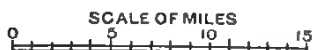
Some of the lakes present interesting marks of the action of ice. The winter's ice, when melted around the shores of the lakes and moved by the wind, frequently drives large boulders for yards before it; these leave long furrows in the mud, and remain, with a mass of small stones and earth, in front of them. In other cases, lakes are in this manner surrounded by dyke-like walls of stones and earth.





GEOLOGICAL MAP OF CAPE BRETON

FROM SURVEYS
BY
H. FLETCHER B.A. & OTHERS
OF THE
GEO. SURVEY OF CANADA
BY
E. GILPIN JR.

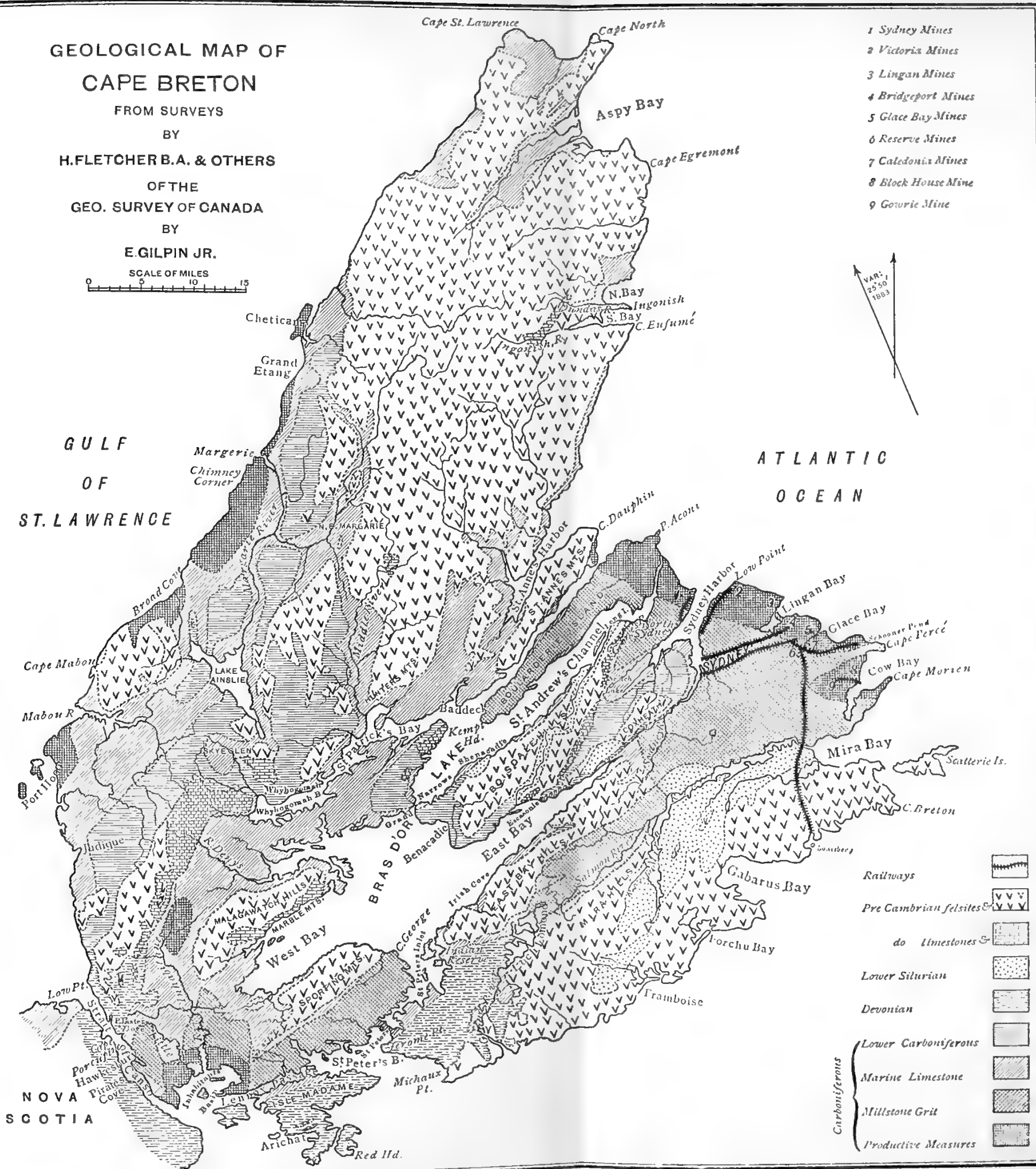


- 1 Sydney Mines
- 2 Victoria Mines
- 3 Lingan Mines
- 4 Bridgeport Mines
- 5 Glace Bay Mines
- 6 Reserve Mines
- 7 Caledonia Mines
- 8 Block House Mine
- 9 Gowrie Mine



GULF
OF
ST. LAWRENCE

ATLANTIC
OCEAN



- Railways
- Pre Cambrian felsites &
- do limestones &
- Lower Silurian
- Devonian
- Carboniferous
 - Lower Carboniferous
 - Marine Limestone
 - Millstone Grit
 - Productive Measures

NOVA
SCOTIA

43. *On some PERCHED BLOCKS and associated PHENOMENA.* By THOMAS M^cKENNY HUGHES, M.A., F.G.S., Woodwardian Professor of Geology, Cambridge. (Read June 23, 1886.)

It is important to record any facts which may throw light on the conditions which prevailed immediately after the age of extreme cold which is commonly spoken of as the Glacial Period.

In the north of England round the Lake Mountains we have many opportunities of examining details where the physical geography is so marked that we may often feel considerable confidence in the interpretation we put upon some of the facts observed. But even there we meet with curious phenomena upon the exact explanation of which we cannot yet with safety insist. Among these is the manner of occurrence of certain perched blocks.

Perched blocks we will define to be masses of rock placed in more or less elevated positions at which they could not have arrived by any of the ordinary operations of nature now in action in that locality. We wish by this to exclude all "tumblers" or masses which have fallen from the cliffs above, such as the "Bowder Stone," in Borrodale, and also rocks trundled along by the mountain-torrents, which often in storm are swollen to the size of great rivers and leave small deltas of loose material or isolated blocks in positions we should never believe them capable of reaching as we watch the silvery trickling thread of water in fair weather.

Some perched blocks may have been dropped off the margin of glacier-ice; some may have been floated on coast-ice or bergs. Among the perched blocks there are some, too, which all would allow had been transported to their present locality by the former action of the ice, though they may have dropped into the exact position they now occupy in much later times, owing to the washing away of the finer part of a great mass of Boulder-clay in which they were imbedded. The removal of this, by postglacial denudation, has left them stranded where they are now found.

But there is yet another class of blocks, the mode of occurrence of which requires some exceptional explanation.

These are what we may call the *pedestal boulders*, that is, blocks perched on pedestals of limestone. The first question is, how were the pedestals formed? and the second, how did the boulders get there? It is on the phenomena connected with these that I propose to offer a few observations.

I will take three groups which have the chief points in common but differ in some important circumstances:—

- i. The boulders near Cunswick Tarn, West of Kendal.
- ii. The boulders on Farleton Knot (the grey-limestone hill which forms such a conspicuous feature on the east of the railway, about halfway between Carnforth and Kendal).
- iii. The boulders on Norber Brow, north of Austwick, in the Craven District.

All these rest upon striated rock; all belong to a rock which

occurs in place close by on the north side; and all stand on pedestals of limestone.

Nos. i. and iii. are Silurian. Those in no. ii. belong to a different horizon of the same limestone as that on which they rest.

The Cunswick boulders have higher ground in front of them in the direct line of transport.

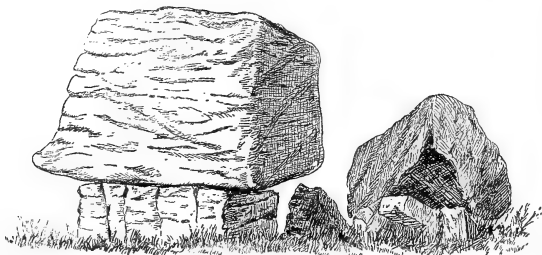
The Farleton-Knot boulders are on ground sloping to the south, but have a very steep hill on the north, up which the ice must have been pushed.

The Norber boulders are some on the north side, some on the south slope of the hill up which they were transported.

Now to examine these cases more in detail.

The Cunswick-Tarn boulders are few in number. There were probably many more, which have been broken up and used for walling. Those which remain stand in a pasture north of the Tarn, which lies in a drift-puddled depression in the Mountain Limestone close under the cliff, towards which, owing to the northerly dip, the beds are slightly inclined. The blocks consist of the roughly cleaved Silurian rock which occurs immediately to the north.

Fig. 1.—*Boulder of Silurian, resting on Mountain Limestone, Cunswick Tarn, Kendal.*



This boulder must have measured originally about $8 \times 6 \times 3$ ft. It has, however, been broken, and only the larger part now rests on a pedestal, which rises some 20 inches above the surrounding grass-covered limestone. The surface of the pedestal is smoothed and furrowed roughly N. and S.

The blocks rest upon pedestals of the Mountain Limestone, standing some 12 to 20 inches above the surrounding rock. This is not so obvious in the case of boulders rising out of pasture-land, as on the bare tables of limestone seen on Farleton Knot or Norber Brow; but even here it can be made out by scraping a little round them.

The tops of the pedestals on which the boulders rest retain the smooth surface given to them by the glacier, and have striæ running north and south. It looks as if just that part of the underlying glaciated rock had been preserved which the boulder had protected from the falling rain, and over which it had prevented the growth

of lichen and moss, while the surrounding surface had been eaten away.

In this case, however, we must be especially careful not to measure the time which it has taken to reduce the surrounding limestone by the height of the pedestal, as this is obviously not due to the rain only, but also and chiefly to the action of the damp soil and vegetation, which has covered it all, up to the very base of the pedestal on which the boulder rests.

On Farleton Knot the boulders, instead of being of Silurian, are of massive Mountain Limestone. They appear to have been generally derived from a thicker bed than that on which they rest. Such a bed occurs a little below the horizon on which they are found, in a part of the series which crops out just over the brow of the hill to the north. The slope of the hill generally coincides with the surface of the beds, but here and there the surface is seen to have been planed off irrespective of the bedding.

Fig. 2.—*Boulder of Mountain Limestone on a Pedestal of Mountain Limestone, Farleton Knot, Kendal.*



This boulder measures 4 ft. 7 in. in greatest length, and 3 ft. 4 in. in height. The pedestal on which it stands rises about 1 foot above the surrounding grass-covered limestone. The striæ on the pedestal run approximately N.E. and S.W.

The pedestals are here rather lower than those of Norber Brow or Cunswick Tarn, being not often more than from 3 to 7 inches high. Some, however, are as much as a foot high, but only in those cases where the growth of vegetation along the master-joints had obviously helped the work. In many cases on Farleton Knot the boulders seem to have protected a somewhat larger surface of the limestone than that immediately below them; but the part of the limestone so preserved was always on the side away from the south-west wind. It seemed also that the boulders and pedestals were breaking down over the whole hill, and here and there one could see a round bump, from 3 to 5 inches high, rising above the general level of the limestone and marking the place where a boulder had formerly been perched. Often the boulder was seen close by, whether pushed off

by tourists or rolled from a pedestal which had perished too far on one side, we could not tell.

The striæ on the surface of the pedestals run about north-east and south-west.

The boulders on Norber Brow were noticed by Phillips in 1827*

Fig. 3.—*Boulder of Silurian, resting on a striated Pedestal of Mountain Limestone, Norber Brow, Austwick, Yorkshire.*



and again in 1855†, when he wrote as follows:—“Geologists will be rewarded for inquiring into the remarkable distribution, over limited breadths, and to elevations somewhat exceeding 1200 feet, of blocks of the slaty and calliard masses which fill a large space about Horton in Ribblesdale, and between this place and the village of Austwick. Here they are *in situ*, occupying what, with reference to the limestone hills around, may be regarded on the whole as a hollow space between two elevated ranges of limestone, of which the northern is the higher, that on the south being depressed by the Craven Fault.

“From this hollow, regarded in a general sense, masses of the slaty rocks have been drifted by some force of water to the south-west, south, and south-east, not merely or even mainly by the valleys, but over the high ground, so as to rest on the limestone hills above

* Trans. Geol. Soc. vol. iii. p. 13.

† ‘The Rivers, Mountains, and Sea-coast of Yorkshire,’ London 1855, p. 111.

Ingleborough House and Austwick, on the elevated ridges of Feizer, on the summit of Giggleswick Scar, and at greater heights on the rugged mountain over Stainforth, Langcliffe, and Settle, and eastward of this place toward the summit of the road to Malham Cove. The greatest elevation reached by the slaty rock *in situ* in the district is about 1160 feet in Moughton Fell, the limestone there rising over it to the height of 1404 feet. It is at about the same height under the bare limestone of Long Scar. The hills on to which it has been drifted southward do not in general rise so high as this; but Feizer is about 30 feet higher, and the point on the hills over Settle which is reached by the blocks, in considerable number and of great magnitude, is not less than 1350 feet, nearly 200 feet above the highest part of the native rock. Still more singular is the fact that the limestone of Long Scar, the hill which rises over the slate to a height nearly the same as that of Moughton Fell, is covered by very many of these blocks brought from below, and scattered on the surface to a height of not less than 1260 feet. The blocks are very often perched; show no marks of abrasion; no other drift matter is with them; they are collected sometimes into small groups; and they may be regarded as having been uplifted and floated by ice, and dropped on surfaces which had been swept by currents clear of other loose matter.

“In lower ground, to the southward, westward, and eastward, the slaty blocks have been carried very much further; in this case they are no longer solitary, but mixed with other sorts of detrital matter, and occasionally show marks of attrition in water, which they never do on the high limestone hills (see the Lithograph).”

In the figure referred to (pl. v. fig. 3) he represents the block as perched on an elevated part of the limestone, but he does not seem to have observed the glaciation of the top of the pedestal; nor does the explanation that the surrounding part of the limestone had perished since the deposition of the boulder where now found seem to have occurred to him.

In a paper read before the Geological and Polytechnical Society of the West Riding of Yorkshire in 1867, I drew attention to these facts as follows:—

“About a mile N. of Austwick, there are some very interesting points connected with glacial phenomena and subsequent denudation. Resting on the mountain-limestone plateau of Norber, there are a number of large blocks of Silurian grit These have been forced along from beds at a lower level in Crummack valley, and left often on a bare table of limestone. Now, as every one must have observed who has walked over these limestone hills, the rock is jointed in all directions, and the water which falls on the limestone, whether as rain, or as small streams, collected on the overlying Yoredale rocks and drift, disappears in the crevices of the limestone. The result is, that there are no streams running over its surface, and all the water which reaches it at any distance from the shale or drift boundary, is the rainfall on that particular spot. Well, this rainfall has been

intercepted by some of the great Silurian boulders, and the result is, that the original face of the limestone has been preserved under them, while all around it has been eaten away by the rain-water, and so the boulder stands on a small pedestal of irregular shape, according as the surface has been more or less protected from the splash and wind-blown rain. We can generally see under some part of these overhanging Silurian blocks, and there we find the limestone smoothed, polished, and strongly furrowed and striated down the valley. Thus we have the print of the old glacier stereotyped as it were in the solid rock, and one good fact clearly recorded to help us to work out the history of the past.

“Another question which naturally suggests itself is, how much of the limestone has been thus carried away by the rain only, and of course the height of the limestone-pedestals above the surrounding part gives us a measure of this. It appears to be generally from 12 to 18 inches. Here, again, we get more data for determining the absolute age of some of these phenomena. Assuming the average periodic rainfall to have been constant, or at any rate to be determinable, and the quantity of limestone removed by a given quantity of rainwater to be known, to find how many years have elapsed since this limestone was first exposed to subaerial denudation”*.

Mr. Tiddeman† also has referred to the manner of occurrence of the boulders on Norber Brow; Mr. Davis‡ mentioned them; and they have been more fully described by Messrs. Davis and Lees§. Mr. Mackintosh|| took up the problem above stated, and offered a numerical estimate of the time which has elapsed since the limestone over which the boulders are scattered was exposed to denudation. As I pointed out in the discussion on that paper, there were too many unsupported assumptions to allow us to attach much importance to the results at which he arrived.

The value of this kind of evidence depends upon the accuracy of the observations on the manner and rate of waste of the particular beds of limestone on which the boulders rest. Every one familiar with the Mountain Limestone knows how some parts stand out in bluffs and some are readily cut back by subaerial weathering. Such overhanging ledges and such hollow places, the rock-shelters of primæval man, are seen in most limestone districts, whether in the newer rocks of the Dordogne or the older rocks of the Elwy and of Farleton Knot. The mode of weathering is determined by small differences in the character of the rock, such as the tendency to break up into thinner beds, the quantity of earthy matter, the crystallization being uniform and complete through great masses, or producing only small concretionary nodules.

* “Notes on the Geology of Parts of Yorkshire and Westmorland, by T. M'K. Hughes, M.A., F.G.S.,” Proc. Geol. Polytechn. Soc. West Riding of Yorkshire, July 1867, vol. iv. p. 574.

† Quart. Journ. Geol. Soc. vol. xxxviii. 1872, p. 477.

‡ Proc. Geol. Polytechn. Soc. W. Riding Yorkshire, vol. vii. 1880, p. 266.

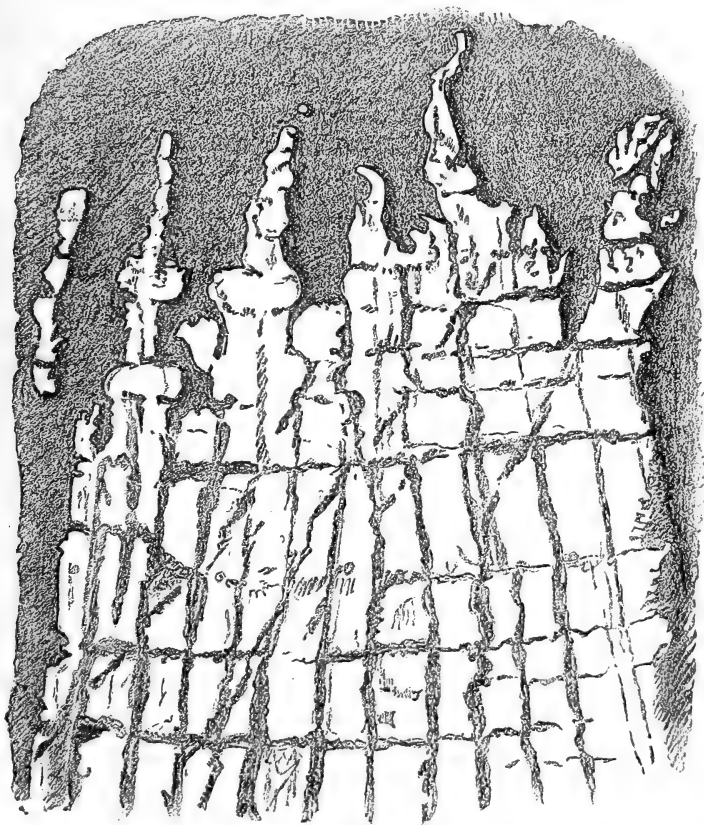
§ West Yorkshire, pp. 200, 201, 267.

|| Abst. Proc. Geol. Soc. Feb. 21. 1883, p. 67.

So when we are examining, not the cliffs but the tops of the hills, we find that the mode of weathering of the limestone is influenced by the same differences of character, and the result is an endless variety of fantastic forms in one case, and a more or less uniform crumbling away in another.

Of external circumstances affecting the mode of weathering of the limestone the most important is the vegetation. We see crevices, where there can never be any mechanical abrasion of the rock, opened out into great chasms as lichen, moss, ferns, and grass successively get foothold in it; and round the margin of the great lime-

Fig. 4.—*Ground-plan showing Mode of Weathering of Mountain Limestone.* (1 inch=2 feet 8 inches.)



stone tables on which the boulders we are describing rest we see the manner in which the rock is eaten back as the vegetation encroaches along the lines of weakness, furnishing more acid and holding more damp (see fig. 4).

We have to ask how far temperature and other climatal conditions may have affected the amount of carbonic acid in the air and the rapidity of growth and decomposition of the vegetation.

Carried through the deep fissures in solution, as a bicarbonate, the dissolved portion of the limestone is again thrown down when the water emerges and is aerated or evaporated, and again offers tempting problems to the speculative who try to give us a geological measure of time from the rate of growth of that most irregular and variable of deposits, the stalactite and stalagmite of our caves.

In the case of a mass of rock on ice, we know that a slab so thin that the sun warms it through melts its way down and sinks into the glacier; but a thick piece of rock protects the underlying ice from the sun's rays, while the surrounding part is melted away, and eventually the rock stands on a pedestal of ice. So in the case of the earth-pillars near Viesch or Botzen, the operation depends upon the locality being to a certain extent protected from side winds and upon the base of the pillars being easily and rapidly drained in such a manner that they are not undermined. Where earth is protected from the straight downpour of rain by an umbrella-like capping of stone, while the surrounding part is washed away, there an earth-pillar is produced.

So we must explain the pedestal boulders of Cunswick, Farleton, and Norber. But in this case the boulder does not merely protect the underlying rock from the mechanical action of the rain or cut off the direct rays of the sun; we have here to take account also of chemical and organic action.

It has been ascertained that even pure water will dissolve two grains per gallon of carbonate of lime, but the water generally contains a varying quantity of carbonic acid caught in the atmosphere. As soon as specks of vegetation fix themselves upon the rock the conditions are entirely altered; not only is there a much larger quantity of carbonic acid, derived from the decomposing plants, but the growing buttons and masses of lichen and moss hold the water like a sponge, fretting the stone away so that it has sometimes been mistaken for pholas-bored rock.

A large boulder placed upon the flat limestone rock keeps off the rain which would destroy the glaciated surface. It further, by cutting off moisture, interferes with the growth of vegetation, and by keeping the rock dry prevents its being broken up by frost; and so these pedestals of limestone seem to have an origin analogous to that of the ice-pedestals on the glaciers and the earth-pillars of Botzen.

It is probable that the top of the pedestals on which the boulders rest does represent a surface which has been exposed ever since glacial times. But in the present state of our knowledge what measure of the rate of waste can we apply to them? or to what can we apply them as a test of age?

The pedestals seem to be gradually perishing; in fact there must be a natural limit to their height. An umbrella held too high will only shelter from perfectly vertical rain; so when the pedestal

has attained such a height that the rain can beat in under the boulder, and grass, which would not grow where there was no moisture, can creep up to the base, the pedestal gets eaten away at its base (probably more on one side than another according to the prevalent winds), and the boulder topples over. So such perched blocks may represent only a stage in the process of denudation, and the approximate uniformity of height of the pedestals may depend upon other circumstances than the time during which they have been exposed.

The pedestals are of the same height only over limited areas ; and that has been much helped by the fact that, in each case, they almost exactly represent the thickness of beds which have readily peeled off. The true pedestal, due directly to the protection of the boulder, is often determined by a bed only a few inches in thickness, while there is generally another similar bedding-plane along which the more rapid denudation accompanying the encroaching grass and other plants has acted and which, arrested at the boulder, gives the impression that the true pedestals are higher and more regular than they really are.

Next, with regard to the mode of transport of the boulders, it must be remembered that they have all obviously travelled in the direction of the furrows on the rock on which they rest, from rock in place close by to the north of them. They are perched in such positions and at such levels as would be difficult to explain on the supposition that they were brought there by floating ice drifting in the direction of the furrows and grounding ; and it would be impossible to imagine that, during the period of emergence, the glaciated surface of the rock could have escaped the wasting action of the waves, while marine currents of no great force would certainly have trundled such boulders along the smooth rock-face and swept them into the valley below.

Nor can the blocks be the heavy remainder of a mass of Boulder-clay, the finer part of which has been removed by denudation ; for the blocks, unlike the varied constituents of the nearest drift, are all fragments of one and the same rock, though the ice must have travelled over a great variety of well-marked formations, all of which are represented in the Boulder-clay.

Here and there, on Farleton for instance, there are a few stray stones of much smaller size than the average *pedestal blocks* and derived from a different source. These may represent some of the regular Boulder-clay not quite scraped off by the last advance of the ice.

Had the drift been removed by the action of water, whether of streams or the sea, so that there was no clay left under and around the large boulders, the rock under them must have been water-worn ; while if there was Boulder-clay round and under them, some would probably be preserved there now. Besides this, had the clay once extended around the boulders, it would have collected the rain-water into rivulets, which would have got under the boulders and destroyed the surface of the limestone.

clay, in which the majority of the stones are rounded and scratched. The eating back of that drift therefore would not leave such a group as the Norber boulders. And they cannot have been blocks carried on glacier ice, as that would imply that they had fallen on to it from higher crags a long way off, whereas in some cases we find that, on the contrary, they came from a rock at a lower level close by.

In the three cases I have recorded, the positions in which the boulders are found would be out of the line of the principal transport of material.

In the case of the Cunswick-Tarn boulders there are no high hills to the north. The stones carried on that part of the ice would have got well down into the mass, which would have gravitated towards the east. In the case of Farleton Knot there must have been a time when the ice just split against the end of the hill and was lifted by it, falling away east and west, carrying deep in the body of the ice, below the level of Farleton Knot, the drift it had brought from a distance.

The situations to which the *Pedestal Blocks* have been carried shows that the ice must have entirely filled the great valleys of the Kent and its tributaries and the smaller valleys opening out into the Craven district, and therefore it must have covered the rock from which the blocks were obviously derived. Now we cannot conceive of any process by which such blocks can have been dug out *under* the ice and carried forward. In every case where these *Pedestal Blocks* are found, the parent rock occurs in place close by on the north side—so near that the variation in the snowfall from one season to another would be sufficient to account for the uncovering of the rock from which they were derived, and the picking up and pushing forward of the loosened masses in succeeding seasons of greater advance of the ice to where the *Pedestal Blocks* now occur.

Since, then, it is almost impossible that the blocks could have been left by icebergs or be the remains of a Boulder-clay all the rest of which has been washed away by the rain, and since the rare occurrence and limited distribution of such groups of *Pedestal Blocks* seem to require in explanation some exceptional conditions—not synchronous but similar local conditions in each case—the following possible explanation, arising out of the observations recorded in the foregoing pages, seems, though not altogether satisfactory, to be the least open to objection with the existing data.

The great ice-sheet had dwindled away and was still rapidly receding. It pushed along tongues of ice down the principal valleys running south from the Lake-district, from the Pennine Range, and from the Yorkshire Moorlands. Then, as now, or then more than now, there were periods of greater cold and precipitation and periods of milder weather, and in consequence the glaciers sometimes advanced, sometimes fell back, on the whole losing ground. When the glacier had receded a little, then, as now, the Silurian grit of Crummack Dale or the thick- and thin-bedded limestone of Farleton

Knot was split up along joints by the weather, and the ground covered with a ruinous heap of broken rock, still in place or only just dislodged, as may now be seen where the water gets into the joints along the outcrop of the Silurian grit a little south of Crummack farmhouse.

A succession of heavy snowfalls, on the other hand, caused a larger body of ice to rise against the western slopes of Kendal Fell, to impinge on the northern end of Farleton Knot, to crowd into Crummack Dale, and carry up and over the brow of the hill the blocks loosened during the previous years when the glacier had receded and left the surface bare.

On Norber Brow this pushing-up hill of the boulders is more marked; for here the blocking of the mouth of the valley by the great ridge of grit that runs across it by Whitestone Wood forced the ice up to higher levels during the temporary advance of the glacier. It had probably receded as far as the precipice at the head of Crummack Dale, and the grit had been broken up by the frost and thaw of many a season when the ice crept forward again.

To sum up, then, it will appear that the simplest explanation of the phenomena described is that the *Pedestal Blocks* of Cunswick Tarn, of Farleton Knot, and of Norber Brow represent the last push of the great glacier over some of the obstructions that lay in its southward course. The glacier in its last advance picked up the boulders due to the breaking up of massive beds exposed to the action of frost and sun when the glacier had receded a little, and pushed them forward a short distance. This was a process which had probably been going on always at the end of the glacier, but it was only here and there that local conditions allowed the record to remain.

No runlets could collect on bare jointed limestone, and therefore there was no denudation except that due to the chemical and mechanical action of the rain and other condensed atmospheric moisture helped by vegetation. Where this was arrested by the protecting boulder the limestone was preserved, while the surrounding part perished, and thus the boulders stand on pedestals of which they were themselves the cause.

DISCUSSION.

The PRESIDENT remarked upon the clear and terse way in which the Author had placed his facts and arguments before the meeting. At the same time he remarked that the case was open to be regarded from two points of view.

Prof. PRESTWICH said that a few years since he had been shown some of these pedestal-perched blocks by Mr. Tiddeman, and that he had come to a different conclusion from the Author upon the question of their affording a test of age, as there seemed to be considerable uniformity in their average height. He instanced the case of surfaces exposed in old Roman quarries. He concluded

that there is no foundation for the assumption of extreme dates. He agreed with the Author that these blocks were the results of the last pushing of the ice, having been dropped during the last glacial phase.

The AUTHOR in reply said the reason why he objected to any numerical estimate of the time which had elapsed since the boulders were left on the glaciated surface was that we knew the rate of weathering in the limestone was most unequal. He gave cases from Devonshire and the Lake-district of extensive weathering in a few years. He had called attention to the great acceleration of decomposition where the vegetation encroached on the limestone, and he maintained that we had no constant measure to apply.

44. *On a new EMYDINE CHELONIAN from the PLIOCENE of INDIA.*

By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read June 23, 1886.)

[PLATE XV.]

AMONG a small collection of fossils from the Pliocene Siwaliks of Perim (Piram) Island, Gulf of Cambay, kindly forwarded to me by Col. J. W. Watson, the Political Agent at Kattiawar, there is the shell of an emydine chelonian which indicates a species distinct from any of those which I have recently described from the Siwaliks*.

The specimen (Plate XV.) consists of the nearly complete shell, and on the dorsal surface exhibits both the impressions of the epidermal horny plates and the sutures separating the subjacent scutes. The plastron, although considerably damaged, is seen to have no joint throughout its length, and is ankylosed to the carapace; there are two pygal plates, and the vertebral scutes are relatively long and narrow. These features indicate that the specimen belongs to the group of the Emydidæ containing the genera *Geoemyda*, *Clemmys*†, *Pangshura*, and *Batagur*‡. That it does not belong to *Pangshura* is at once evident; and its general characters lead to the conclusion that it should be referred either to *Clemmys* or *Batagur*. In the case of medium-sized fossil species it is frequently a matter of extreme difficulty to say to which of these two allied genera they should be referred; but as the fossil apparently comes nearest to certain species of *Clemmys*, and is not of the large dimensions characteristic of many species of *Batagur*, I think it may be referred to the former genus.

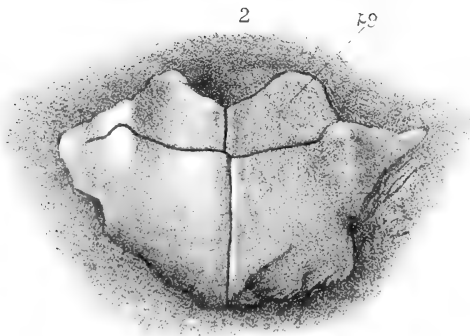
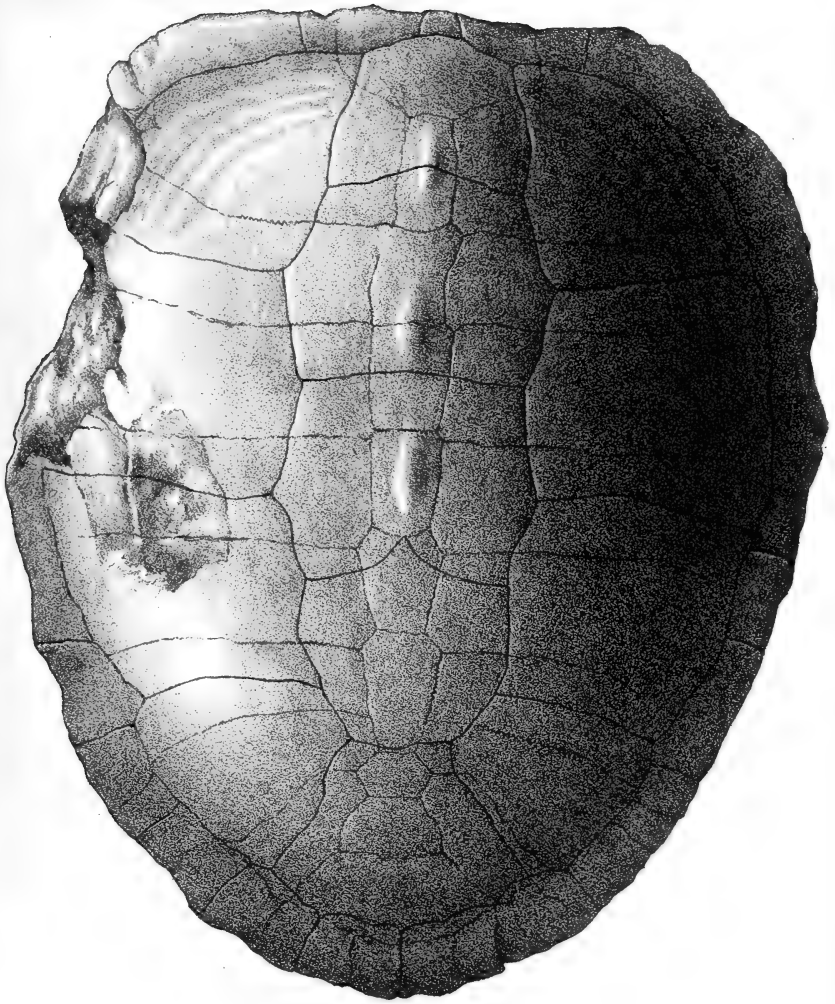
The rim of the anterior marginal scutes has been broken off, and there is some imperfection on the left side of the carapace. The carapace is well vaulted and of great relative width, the length being 8, the width 7, and the height 4·4 inches; the condition of the sutures indicates that the specimen is adult.

It cannot be determined whether the anterior margin of the carapace was notched or not, but the posterior margin is entire. The nuchal plate was evidently narrow, and broadest posteriorly. The first vertebral plate is narrowest anteriorly and has a tendency to a bell-shape, its length being very nearly equal to its width. The second and third vertebrae are subhexagonal and relatively broad. The fourth is not larger than the third, and is narrowest posteriorly; it gives off a small process in the middle of the anterior border which projects into the third vertebral. The fifth vertebral is of normal form. There is an interrupted vertebral keel, which forms well-marked prominences on the fourth and fifth vertebral scutes, but no trace of costal keels. There are well-marked costal areolæ, which are nearer to the marginal than to the vertebral plates. It will be

* See 'Palæontologia Indica,' ser. 10, vol. iii. pt. 6 (1885).

† For the sense in which this genus is employed see 'Palæontologia Indica,' tom. cit. p. 170.

‡ The small forms separated by Gray as *Morenia* are referred by some writers to this genus, and by others to *Clemmys*.



A. Hannond del.

CLERMYS WAYSONI.

H. De la Beche sculp.

unnecessary to describe the form of the vertebral scutes, as they are not generally visible in specimens of the shells of existing species. On the plastron the only important point that can be detected, is that the inner border of the postgular plate (fig. 2, *pg*) is very short antero-posteriorly, and was probably exceeded in length by the intergular suture.

As I have already mentioned, the fossil is certainly distinct from all the Siwalik chelonians which have yet been described, and I have been unable to identify it with any existing Asiatic species. It apparently comes nearest to *C. sinensis**, but differs by the much narrower nuchal plate, and by the first vertebral being narrowest anteriorly, as well as by the greater breadth of the whole shell and the less gibbous profile of the hinder half of the carapace; both forms agree in the nature of the costal areolæ and the shortness of the inner border of the postgulars†.

There are indistinct lateral keels in the existing species, but it is quite possible that these would be invisible in a fossil condition. *C. pygolopha*, Peters‡, from the Miocene of Styria is apparently an allied form, which is, however, markedly distinct from the fossil under consideration.

Since, then, no other existing species appears to come as close as *C. sinensis* to the Perim fossil, while it is improbable that the latter should be identical with a non-Asiatic form, I think it may be regarded as a new species, for which I propose the name of *Clemmys Watsoni*, in honour of the donor of the type specimen.

The species may be defined from the characters of the shell as follows:—"Shell moderately vaulted, globose, broad; posterior margin entire; nuchal plate narrow, and broadest posteriorly; first vertebral narrowest anteriorly, and showing a tendency to a bell-shape; second and third vertebrae hexagonal, fourth short, narrowest posteriorly, and giving off a process jutting into the posterior border of the third; an interrupted vertebral, but no costal keel; costal areolæ well-marked; suture separating the postgulars much shorter than the intergular suture."

I may add that Col. Watson has presented the specimen to the British Museum.

EXPLANATION OF PLATE XV.

Clemmys Watsoni, Lyd.—The carapace (fig. 1) and anterior part of the plastron (fig. 2); from the Siwaliks of Perim Island, Gulf of Cambay, India. $\frac{1}{2}$ nat. size. *pg*, postgular plate. British Museum.

* Compare Gray 'Cat. Shield-Reptiles Brit. Mus.' pt. i. pl. vii.

† *Morenia Bermorei* makes some approach to the fossil in several characters, but is at once distinguished by the greater length of the inner border of the postgulars.

‡ Denkschr. k. Ak. Wiss. Wien, vol. xxix. pl. ii. (1869).

45. *On the DECAPOD CRUSTACEANS of the OXFORD CLAY.* By JAMES CARTER, Esq., F.G.S., F.R.C.S., &c. (Read June 23, 1886.)

[PLATE XVI.]

THE communication which I have the honour to offer to the Society relates to the Decapod Crustaceans of the Oxford Clay. It would appear that the investigation of this class of fossils, as represented in the British Middle Jurassic rocks, has been very incompletely carried out. The number of species which have been recorded as occurring in this country is very small, and scarcely any of those which are known to occur have been figured or described in sufficient detail for specific determination. Moreover, the bibliography of the subject is extremely limited. As regards the Oxford Clay in particular, the only species mentioned in the 'Catalogue of British Fossils,' published by the late Professor Morris in 1854, as belonging to that formation is *Mecochirus Pearcei*, and the same species is the sole representative contained in the very valuable special 'Catalogue of British Fossil Crustacea,' published in 1877 by Dr. Woodward, to whose persistent researches and numerous publications so large a portion of all that is known on the subject is justly attributable. Since the publication of his Catalogue, Dr. Woodward has described and figured two new species, *Mecochirus Peytoni* and *Callianassa isochela*, both from the Kimmeridge Clay; but I am not aware that either of these forms has hitherto been found in the Oxford Clay. In the recent most valuable edition of Phillips's 'Geology,' Mr. Etheridge states that *Glyphea leptomana*, *G. Stricklandi*, and *Mecochirus Pearcei* constitute the Macrurous Crustacean fauna of the Oxford Clay; and this statement is repeated and confirmed in the works of most authors, with scarcely any additional facts or information. Moreover, I have found most of the collections which I have had the opportunity of consulting to be completely barren of examples.

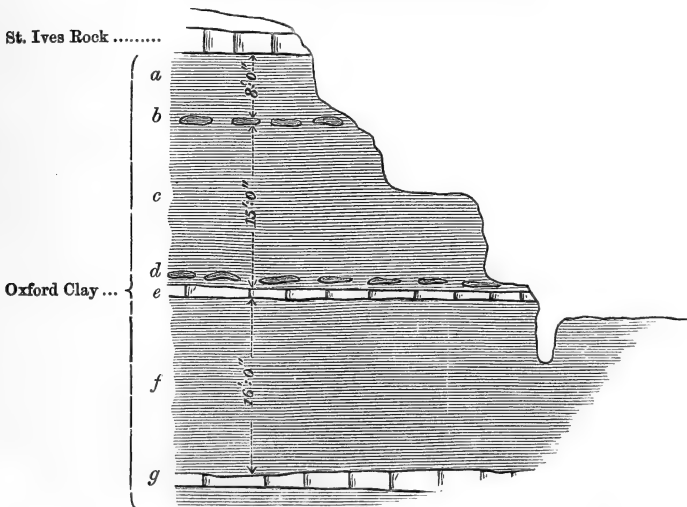
From this paucity of evidence, and this general absence of specimens from collections, it may be inferred that the remains of Oxfordian Crustaceans are generally of rare occurrence. The discovery, however, of a considerable number and variety of forms in one locality of limited area proves that decapod crustaceans actually did exist, and were somewhat abundantly represented during the Oxford Clay period, and at the same time suggests the probability that the absence of specimens in other localities has resulted from non-preservation. The locality to which I refer is St. Ives, Huntingdonshire. Mr. Thomas George, F.G.S., who is at present engaged in most useful work in the Museum of Northampton, has carefully investigated the geology and assiduously collected the fossils of the Oxford Clay as it occurs in that district, where it is quarried for the purpose of brickmaking. He has obtained an extensive series of specimens of Crustaceans which he has most liberally placed at my disposal for description; and these, together with the examples in the National, the Woodwardian, the Oxford, and other Museums,

which I have very courteously been allowed to consult, collectively form materials for a more complete knowledge of the Oxfordian Crustaceans than has hitherto been possible.

I will first allude to the forms which have been obtained from St. Ives, and afterwards briefly notice those from other localities.

The consideration of a group of fossil forms found associated in any one particular horizon has always a special interest, both biological, palæontological, and geological; and the degree of interest depends in great measure upon the precision with which such stratigraphical position can be defined. Therefore, before describing the fossils, I will point out the horizon from which they were obtained. I am able to do this definitely by the kindness of Mr. Roberts, F.G.S., of the Woodwardian Museum, who has recently critically examined the district of St. Ives, and has embodied the results of his observations in the yet unpublished essay which has secured to him the honour of the Sedgwick Prize. Mr. Roberts states that—"The fossil Crustacea found at St. Ives come from the large clay-pit which lies immediately to the west of that town. The pit is opened in the Oxford Clay, and, at the present time, shows the following section:—

Section in Clay-pit west of St. Ives.



	ft.	in.
St. Ives Rock	3	0
Oxford Clay. (a) Dark blue clay	8	0
(b) Calcareous nodules		9
(c) Dark blue clay	15	0
(d) Calcareous nodules	9 to 10	inches.
(e) Argillaceous limestone	1	0
(f) Blue clay, which at one time was worked to a depth of ...	16	0
(g) Limestone		(thin bed)

"The clay is of a dark blue colour throughout, and its upper part contains a considerable quantity of small selenite crystals. The limestone is of greyish colour and very impure, and occurs in the form of nodular bands or regularly bedded; the beds, however, are not constant.

"The Oxford Clay is overlain by a bed, 3 feet thick, of brown ferruginous limestone, locally known as the St. Ives rock, now seen only in a small exposure near the western boundary of the brickyard. There has been some difference of opinion as to the geological horizon to which this limestone belongs. Professor Seeley maintains that it lies about 130 feet down in the Oxford Clay, whilst it is mapped by the Geological Survey as Lower Calcareous Grit; and further, Messrs. Blake and Hudleston are of opinion that it belongs to some part of the age of the Lower Calcareous Grit, or even higher. I have elsewhere shown (Sedgwick Essay for 1886) that, from a consideration of its fossils, and also on stratigraphical grounds, the St. Ives Rock must be placed on the horizon of the Lower Calcareous Grit. The following fossils, among others, occur in the St. Ives Rock, all of which are characteristic of the Lower Calcareous Grit of other areas:—*Amm. perarmatus*, *Modiola bipartita*, *Waldheimia bucculenta*, *W. Hudlestoni*, *Collyrites bicordata*.

"Assuming, then, that this is the true position of the St. Ives Rock, it necessarily follows that the clays in the St. Ives clay-pit which come below it must belong to the uppermost zone of the Oxford Clay; and this view is supported by the fact that the fossils found in the clay at St. Ives are precisely similar to those which occur in this horizon of the Oxford Clay in other parts of England.

"Subjoined is a list of the most common fossils from the clay of the St. Ives pit:—

" *Ammonites athleta*.
 — *cordatus*.
 — *Mariæ*.
 — *Lamberti*.
 — *dentatus*.
 — *Eugenii*.
 — *Jason*.
 — *perarmatus* (rare).
Belemnites Puzosianus.

Alaria trifida.
Nucula nuda.
Leda lacryma.
Cucullæa concinna.
Gryphæa dilatata (in abundance).
Waldheimia impressa.
Terebratulæ oxoniensis.
Acrosalenia, sp.
Serpula, sp."

Most of the Crustacean specimens are more or less mutilated, and correspondingly difficult of positive specific determination. In all cases, therefore, when in doubt whether a specimen was identifiable as a described species, I have thought it better to consider it with reference to its allied forms, than to regard it as a new species. Some of the species which I have to mention are indicated by the occurrence of their chelæ only. I have had considerable hesitation in deciding how far it was warrantable to regard the occurrence of detached limbs as sufficient evidence of the existence of a distinct form; but it seems probable that in some genera the carapace was so thin and fragile as scarcely to admit of preservation in a recognizable form, and that only the more solid portions of the test, the

chelæ &c., are preserved, and constitute the only evidence available. It therefore seems desirable, as affording a more complete knowledge of the Crustacean fauna of the period, to record the occurrence of these detached chelæ rather than pass them over unnoticed.

The Huntingdonshire specimens which have come under my observation I have ventured to refer to some 15 or 16 distinct species. So far as I have been able to ascertain, none of these have been described in any English publication, nor has their occurrence in Britain been previously recorded, with the exception of one species of *Eryma* (*E. Babeaui*) mentioned by Mr. Etheridge as having been found in the Kimmeridge Clay. I am of opinion that seven species can be identified as forms which have been described by foreign palæontologists, and seven I have been induced to regard as new to science.

The genus	<i>Eryon</i>	is represented by	1	species.
„	<i>Eryma</i>	„	5 or 6	„
„	<i>Glyphæa</i>	„	2	„
„	<i>Magila</i>	„	2 or 3	„
„	<i>Mecochirus</i>	„	1	„
„	<i>Goniochirus</i>	„	1	„
„	<i>Pseudastacus?</i>	„	1	„
„	<i>Pagurus?</i>	„	1	„

ERYON SUBLEVIS, nov. sp. (Pl. XVI. fig. 1.)

Carapace about one fifth wider than long, strongly arched transversely; interorbital portion of frontal border widely emarginate, beaded by an edge of small tubercles (antero-lateral border broken); that of the postero-lateral region gradually inclining inwards posteriorly, and fringed by a series of acute, slender, marginal spines. Cervical sulcus narrow, crossing the central dorsal ridge about midway between the frontal and the posterior border; gastric regions rather intumescent. The surface of the cephalic portion bears numerous, small, round tubercles, regular in size, but irregular in disposition; a strong lens renders visible minute puncta between the tubercles; similar but more scattered tubercles occur on the outer portions of the scapular regions, but the spaces between the central and the lateral branchial ridges are smooth; the metabranchial regions are strongly deflected laterally. A strong, central, longitudinal ridge, crowded with tubercles, extends from the posterior border of the carapace, crosses the cervical sulcus, but does not reach the frontal border; and on each side of it, about one fifth nearer to it than to the postero-lateral border, is a similar, nearly straight, lateral, scapular ridge. These lateral carinæ interrupt the cervical sulcus, but are not distinctly traceable in front of it (posterior border of carapace imperfect). First pair of chelæ of moderate size; basal portion of propodite (hand) about half the length of the carapace, smooth; fingers slender, equal; carpodite half as long as the hand.

Compass-measurement. Carapace $2\frac{5}{8}$ inches wide and 2 inches

long; distance between inner angles of orbits $\frac{3}{4}$ of an inch; length of hand $\frac{7}{8}$ of an inch; width one third of the length.

Oxford Clay, St. Ives.

Coll. Woodwardian Museum; collected by Mr. Keeping.

I have not been able to identify this fine species with any described form. It resembles *E. barrovensis*, McCoy, from which, however, it is distinguished by the highly vaulted form of the carapace, by the greater comparative width of the interorbital portion of the frontal border, by having shorter lateral scapular ridges, and by the absence of surface tubercles in the spaces between these and the central dorsal ridge, also by having the dorsal surface of the propodite of the first pair of chelæ smooth instead of granulated. The smoothness of the mid-scapular region and the existence of a sharply defined cervical sulcus will distinguish this species from *E. arctiformis*, Schloth. It is allied to *E. calvadosii*, Morière, and also to *E. Edwardsii*, Mor., from the Upper Lias (Calvados), figured and described by M. Morière (Bull. de la Soc. Linn. de Normandie, sér. 3, t. vii. et viii.). It is distinguishable from both those species by the smoothness of the mid-branchial region, and, so far as can be determined by the single imperfect specimen from St. Ives, by the form of the carapace; the postero-lateral borders are straighter and slightly sigmoidal, and bear longer and fewer marginal spines.

In the only specimen I have seen, the carapace is so imbedded in the pyritous matrix that the outline of the antero-lateral border cannot be determined. The specific name applies to the smoothness of the mid-branchial region.

ERYMA MANDELSLOHI, Meyer, sp. (Pl. XVI. fig. 2.)

Klytia Mandelslohi, Meyer, Neue Gatt. foss. Krebse, p. 21, tab. 4. fig. 30.

Eryma Mandelslohi, Oppel, Pal. Mitth., tab. 5. fig. 3; Etallon, Notes sur les Cr. Jur. d. Bass. du Jura, pl. viii. fig. 8 d.

Cephalothorax longer than high, in the proportion of 7 to 4; dorsal surface throughout impressed with rather large, deep punctations, which have irregular borders, and are so closely arranged as to produce a more or less reticulate appearance; small round tubercles are irregularly scattered over both the cephalic and scapular regions, some of which are placed at the posterior edge of a punctation, but others have no such definite relation. All the sulci are deep and wide; the epibranchial lobe is large, well defined, and approximately parallel-sided. Mesobranchial small; metabranchial more closely foveated than the other lobes. Chelæ of first pair large, of equal size, robust, rather longer than the cephalothorax; dorsal surface of the hand with a few small tubercles, and closely punctated, as also is the palmar side; fingers as long as or rather longer than the hand, both slightly incurved in a parallel direction, and distinctly foveated on both sides, the foveæ being larger than those on the hand; outer border rounded; inner margin with a series of small, dentary tubercles. These chelæ vary con-

siderably in size and form. Length of carapace 30 millim.; height of carapace 15; length of chelæ 30; width of propodite 14.

Oxford Clay, St. Ives.

Specimens exist in Mr. George's and my own collections, and in the British, Woodwardian, and Oxford Museums.

The St. Ives specimens are of larger size than those figured by Meyer and Opper, and the cephalothorax is relatively less elongated in form; it also differs in that the tubercles on the anterior moiety are larger and more numerous.

The Oxford Clay carapace figured by Etallon (Cr. Jur. pl. viii. fig. 8 *d*) represents the Huntingdonshire form much more nearly than does that of Opper from the Kellaways Rock. The latter author in his description (Pal. Mitth. p. 29) does not mention the occurrence of tubercles on the surface; but by the courtesy of Prof. von Zittel I have had the opportunity of examining the original figured specimen, and have ascertained that tubercles do exist, but are of relatively smaller size than on the St. Ives specimens. Etallon mentions this character as existing in specimens which have come under his observation. It seems not improbable that it may prove to be desirable to regard the Huntingdonshire form as a distinct species, by reason of the difference in the form of the carapace and in the character of the tuberculation. If so, I would suggest the specific name of *E. Etalloni* in honour of the distinguished palæontologist, who has contributed so largely to our knowledge of fossil Crustaceans. Specimens occur somewhat abundantly at St. Ives.

ERYMA VENTROSA, Meyer, sp.

Klytia ventrosa, Meyer, Neue Gatt. foss. Krebse, tab. 4. fig. 29.

Eryma ventrosa, Etallon, Notes sur les Cr. Jur. du Bass. du Jura.

I have seen two specimens of this species, each of them showing a nearly complete carapace, the characters of which correspond with those given by Meyer and Etallon, and also with those of a plaster cast of a specimen from Mailley, Haute Saône, for which I am indebted to the courtesy of Prof. von Zittel. They are of somewhat smaller size, and the carapace is not quite so long in proportion to the height—16 millim. by 30 millim.; the Mailley form 20 millim. by 40 millim. The tubercles also are more closely arranged in the St. Ives specimens, about 10 in a quarter-inch on the metabranchial region. In some portions of the carapace of one of the specimens a crescentic depression occurs in front of each tubercle; this is a character which Etallon (Cr. Jur.) assigns to *E. subventrosa*. A chela of the second (or third?) pair of limbs has the hand about three times as long as wide, with straight, subequal fingers half the length of the hand, each impressed by a series of rather large, setigerous pits.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton.

Two specimens examined.

Etallon gives a full analysis of the characters of this species, which appears to be a widely distributed form.

ERYMA VILLERSI, Mor. (Pl. XVI. fig. 3.)

Eryma Villersi, Morière, "Prem. Note sur les Cr. de l'Oxfordien trouvés dans le Calvados," Bull. Soc. Linn. Norm. sér. 3, t. vi. pl. i.

"Chelæ of first pair robust;" fingers long, slender, subequal in size, rendered slightly sinuous in outline by a gentle longitudinal double curvature; subcompressed laterally (oval in section); surface with depressed, small, regular tubercles, two or more diameters apart; outer border of both fingers broadly rounded; inner border of fixed finger with a series of denticles, of which a few are raised on a prominence near the proximal end; a series of smaller size occur between this prominence and a single large tooth about the middle of the finger, beyond which the series is continued to the distal end.

The inner margin of the dactylopodite bears a row of denticles unequal in size and rather larger than those on the fixed finger; those on the second proximal fifth of the dentary border are the largest, and are opposed to the small denticles of the fixed finger.

These chelæ so precisely agree in character with those of the specimen figured and described by M. Morière from the Oxford Clay of Calvados, that I do not hesitate to regard them as identical. M. Morière has figured a nearly perfect carapace with the first pair of limbs *in situ*; he also figures (fig. 5) a portion of a long slender-fingered chela which he is of opinion probably belonged to a different species; I have met with the same form amongst the St. Ives specimens, and also with chelæ almost identical with those represented by fig. 2 in M. Morière's plate. This distinguished palæontologist apparently hesitates to separate *E. Villersi* from *E. Babeaui*; both these forms occur at St. Ives, and I am inclined to regard the difference of character as fully sufficient to warrant specific distinction.

Length of dactylopodite nearly 3 inches; width of the distal end of hand about $\frac{7}{8}$ of an inch.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton, and my own.

Specimens examined 8.

ERYMA BABEUI, Etal. Notes sur les Cr. Jur. tab. viii. fig. 1; Oppel, Pal. Mitth. tab. x. fig. 3.

Several imperfect specimens have come under my notice which so nearly resemble those of *E. Babeaui* that I provisionally refer them to that species, although they differ in some details from the figures and descriptions given by Etallon and by Oppel. One rather large specimen shows the distal end of the hand and the greater portion of both fingers, which latter are more robust, but have the graceful, falcate form expressed in the figure quoted. The tubercles on the distal portion of the hand and on the fixed finger are more crowded than in *E. Babeaui* as represented by Etallon and by Oppel, being scarcely more than one diameter apart, but are tolerably regular and uniform in size; those on the dactylopodite

are not uniform, but gradually increase in size as they approach the outer border, where they become more prominent, especially on the proximal portion; the tubercles are conical at the base, flat-topped, with a central mamilla on the summit.

On several small specimens of the dactylopodite the tubercles are more uniform in size and are less crowded. Etallon figures the denticles on the proximal portions of the dentary border of the fixed finger as being considerably longer than the rest, and Oppel states that this character occurs on the dactylopodite; but the St. Ives specimens do not exhibit this feature on either finger.

Width of distal end of hand $1\frac{1}{4}$ inch; length of dactylopodite $2\frac{3}{4}$ inches.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton.

Specimens examined 4.

Mr. Etheridge mentions (Phillips's Manual, part 2, p. 475) that *Eryma Babeaui* occurs in the Kimmeridge clay.

ERYMA GEORGII, nov. sp. (Pl. XVI. fig. 4.)

Carapace nearly twice as long as high; all the sulci large and so deep as to render the several lobes ventrose; the dorsal surface of all the regions bears rather large, conical, but not very prominent tubercles, which are uniform in size and regularly disposed, about one and a half diameter apart, and four or five in a quarter of an inch. (Frontal region imperfect.) Chelæ of first pair of limbs robust; the length of the hand is rather greater than the width of its distal end, and rather more than half the total length of the carapace; it bears regular tubercles which are rather smaller and more crowded than those on the carapace. The fingers are subequal in size, rather longer (?) than the hand, both slightly curved in the same direction, nearly smooth and punctated; outer border rounded; dentary margin with a series of small, depressed, dentary tubercles. Carpopodite two fifths of the length of the hand, and with a few tubercles; distal end of the meropodite with a stout spine. A chela of the second (or third?) pair, of small size, has straight, slender fingers, which are nearly as long as the hand, and both are impressed by several setigerous puncta.

Length of carapace from frontal to posterior border $1\frac{5}{8}$ inch; height of carapace nearly 1 inch.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton.

Specimens examined 3.

I have not been able to identify this form with any described species.

The deep regional sulci and the large size of the tubercles on the dorsal surface of the carapace distinguish it from its allies *E. ventrosa*, *E. propinqua*, *E. numismalis*, and *E. elegans*. It nearly resembles *E. Greppini*, Opp., from which, however, it differs in the conformation of the anterior portion of the carapace and the larger size of the surface-tubercles. The chelæ of this species bear no resem-

blance to the comparatively slender long-fingered claw figured by Etallon (Bull. de la Soc. Géol. de France, sér. 2, t. xvi. pl. vi. figs. 2, 3, 4) as presumably that of *E. ventrosa*. I dedicate the species to Mr. George, in recognition of the value of his palaeontological labours.

In the specimen figured the carapace rests upon one of the chelæ.

ERYMA? PULCHELLA, nov. sp. (Pl. XVI. fig. 5.)

Chelæ of first pair of limbs 5 millim. in length; hand about as long as wide, moderately convex transversely; borders compressed into a blunt longitudinal keel or ridge; dorsal surface with small tubercles, regular in size and distribution, not quite a diameter apart. Fingers about as long as the hand, granulated on outer border; fixed finger slightly recurved at apex; both fingers carry a series of similar denticles on the dentary border. Carpopodite about half as long as the chela, granulated like the hand, as also is the meropodite. Portions of several of the posterior claws remain in the matrix; they are slender, smooth, and have a series of granules on their posterior border.

I provisionally refer these delicate little chelæ to a species of *Eryma*. Several forms of this genus, similarly small in size, occur in the Solenhofen beds, but *E. pulchella* appears to be quite a distinct species.

Oxford clay, St Ives.

Coll. Mr. George, Northampton.

Specimen examined 1.

GLYPHEA HISPIDA, nov. sp. (Pl. XVI. fig. 6.)

Length of cephalothorax nearly twice and a half the greatest height. Cephalic portion one fourth shorter than the scapular. A slight, sharp, longitudinal, central keel, the posterior half of which is closely subtended on each side by a series of tubercles, extends forwards from the cervical sulcus to the rostrum; three other stronger, equidistant ridges, each crested by a series of acutely pointed tubercles, occur in the space between the mid-dorsal keel and the antero-lateral border; the interspaces between these ridges are smooth, but a few tubercles occur on their proximal portion, especially on that nearest the antero-lateral border. A ridge, bearing a string of small round tubercles, follows the contour of the antero-lateral margin. Cervical sulcus very distinct. The surface of all the lobes of the scapular portion is uniformly covered by rather large tubercles scarcely a diameter apart, having apices which, in well-preserved specimens, are very acute and point forwards. The combined epibranchials form a large central lobe, rather acutely pointed posteriorly; mesobranchial lobe clavate, distinctly defined by a sulcus posteriorly, less so anteriorly; a well-defined small lobe occurs between the lower end of the mesobranchial and the hepatic lobes, the latter being separated from the metabranchial by a very faint sulcus. Metabranchials large. Numerous fragments of the limbs occur, which indicate that they were of considerable length:

propodite of the first pair about three fourths the length of the carapace, and three or four times as long as wide, subterete, with one side flattened; the rounded portion has several, 6-10, rows of pointed tubercles; the inner border is compressed, trenchant, and, as in some other species of *Glyphea*, bears an interrupted series of large and small teeth, the terminal one of which extends beyond the distal end and constitutes a rudimentary fixed finger. (Dactylopodite imperfect.) A specimen exhibiting a portion of one of the antennæ indicates that they were long and multi-articulate.

Carapace 24 millim. long; 11 millim. high.

Rare in the Oxford Clay, St. Ives.

Coll. Specimens are in the collections of Thomas George, Esq., and in my own; also in the Woodwardian Museum.

This species is allied to *G. pustulosa*, Meyer, *G. Etallonii*, Opp., and *G. Münsteri*, Voltz. From the two former it is distinguishable by the difference in the carination of the cephalic portion of the carapace, and in the form and proportions of the epibranchial lobe. The characters of the cephalothorax are very similar to those of *G. Münsteri* as figured by Meyer (Neue Gatt. Foss. Kr. tab. iii. fig. 23), but a difference appears to exist as to the cephalic carinæ, and Meyer's figure does not indicate the ridge of tubercles alongside the posterior portion of the central cephalic carina. The chelæ of the first pair of claws, which are fortunately preserved *in situ* in a St. Ives specimen, bear no resemblance whatever to those figured by Meyer (*l. c.* tab. iii. figs. 24, 25). Oppel's enlarged figures of *G. Münsteri* (Pal. Mitth. tab. xvii. figs. 4, 5) differ considerably from those of Meyer, and do not at all apply to the Huntingdonshire specimens. Much confusion exists, especially among continental palæontologists, as to *E. rostrata*, Phillips, which is, however, a well-marked and quite distinct species, as both Dr. Woodward and Professor M^cCoy have determined, and does not occur in the Oxford Clay, so far as I know.

GLYPHEA REGLEYANA, Meyer, Neue Gatt. Foss. Krebse, tab. iii. figs. 14-21; Etallon, Notes sur les Cr. Jur. tab. iii. figs. 11, 12; Oppel, Pal. Mitth. tab. xvii. figs. 2, 3.

A single specimen, consisting of a portion of the carapace, which exhibits the postero-lateral border and the metabranchial lobe, and also several segments of all the limbs of the left side, presents characters which so nearly agree with those of *Glyphea Regleyana* as fully to warrant provisional reference. The portions preserved do not afford any details in addition to those given in full by Meyer, Etallon, and Oppel, except that the meropodite of the anterior two or three pairs of limbs bears a row of acute spines on the posterior, and a series of smaller ones on the anterior border. The surface of the carapace is tuberculated, but is too much worn to determine whether it was also punctated.

M. Etallon observes that this species has a wide range, both geo-

logical and geographical, and Prof. Oppel quotes its occurrence at Malton, Yorkshire.

Length of carapace $1\frac{5}{8}$ inch; length of meropodite of first pair 1 inch.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton.

MAGILA PICHLERI, Opp. Pal. Mitth. tab. xi. fig. 5.

Chelæ short; length of hand, from carpal to dactylar articulation, about equal to its width at the distal extremity; surface with minute, equal, round granules, those on the palmar side having a tendency to assume a definite reticulate arrangement; a few larger tubercles border the articulation for the dactylopodite; outer border of hand carinated by a ridge, which bears a few teeth and is continued as a sharp edge along the fixed finger, closely subtended by a series of puncta on the palmar surface. Fingers about as long as the hand, smooth, flat on the palmar, convex on the dorsal side; inner border of fixed finger gradually widening from apex to base, longitudinally grooved; a series of small, equal, denticles occur on the dorsal edge of the groove, which is sharply angulated near its distal end, giving the characteristic emarginate appearance to the finger. Dactylopodite nearly identical in character with the fixed finger, but rather longer, and the distal emargination is scarcely so distinctly marked.

Dr. Oppel has figured this species, but has not described it in detail.

Length of chela 18 millim.; width of hand 9 millim.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton; my own.

Specimens examined 5.

MAGILA LEVIMANA, nov. sp. (Pl. XVI. fig. 7.)

Chela of first pair—basal portion of propodite (hand) about two thirds as wide as long; dorsal surface slightly convex, smooth, margins broadly rounded. Fingers about as long as the hand, smooth, slender, oppositely curved, convergent at their tips. A slight angulation on the dentary border of the dactylopodite renders its distal half broadly emarginate. Portions of several segments of the abdomen accompany the chela, and indicate the macrurous form; the epimera are rounded, deeply punctated, and margined by a distinct ridge.

The broadly rounded borders of the hand will at once distinguish this species from *M. Pichleri*, Opp.

Length of chela 8 millim.; width of hand 4 millim.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton.

Specimen examined 1.

MAGILA DISSIMILIS, nov. sp. (Pl. XVI. fig. 8.)

Chelæ small, delicate, laterally depressed; propodite (imperfect

posteriorly), anterior portion with minute, round tubercles, two or more diameters apart, on both dorsal and palmar surfaces, most numerous near dorsal base of fixed finger; distal portion of outer border flattened, margined by distinct ribs, which extend along the fixed finger nearly to its apex; the proximal moiety of these ribs is delicately granulated; the border of the hand corresponding to the dactylopodite is rounded. Fingers longer than the hand, flattened laterally, cultriform; surfaces smooth, with a few setigerous puncta; outer edge flattened like that of the fixed finger, and separated from both the palmar and dorsal surfaces by a distinct ridge; the distal three fourths of the dentary border of the fixed finger bear 10 or 12 small subequal denticles; the proximal fourth is occupied by a single larger and longer denticle; the dentary border of the dactylopodite is trenchant, and divided into three nearly equal portions by two slightly prominent denticles or angulations.

I refer these elegant little chelæ provisionally to the genus *Magila*; the specific name indicates the dissimilarity of the dentary edge of the fingers.

Length of chela 16 millim.; width of hand 5 millim.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton; my own.

Specimens examined 2.

MECOCHIRUS SOCIALIS, Meyer, sp.

Eumorphia socialis, Meyer, Palæont. Bd. i. tab. x. figs. 2-10.

Mecochirus socialis, Oppel, Pal. Mitth. tab. xxii. figs. 2, 3.

Length of carapace from apex of rostrum to posterior border about twice and a half its greatest height; test thin and fragile; surface closely and rather coarsely punctated; puncta most numerous near the ventral border of the branchial lobes, gradually disappearing towards the dorsum; each in front of a minute tubercle. A sharp, narrow, cervical sulcus, extending obliquely forwards and downwards on each side from a point somewhat in front of the middle of the dorsum towards the antero-lateral angle, marks off the cephalic portion, which occupies scarcely more than a fourth of the total surface of the carapace; a slightly curved lateral cephalic ridge runs from a small blunt spine on the frontal border nearly to the cervical sulcus; between this ridge and the antero-lateral border a distinct cluster of tubercles occurs. None of the typical lobes of the scapular region are definitely recognizable, except that a sharp U-shaped sulcus, near the antero-inferior angle of the metabranchial, indicates the lower extremity of the mesobranchial lobe; in some specimens the posterior arm of the U is prolonged obliquely backwards and upwards as a faint posterior mesobranchial sulcus.

Rostrum simple, rather short, rapidly widening posteriorly and longitudinally depressed in the mid-dorsal line. Abdomen about a third longer than the cephalothorax; the first segment is the shortest, and has in front a transverse ridge with a small lateral tubercle; a similar ridge crosses the posterior border; the second

is rather the largest of the segments. The epimera are somewhat elevated in the central portion, bear several tubercles, and have broadly rounded and flattened margins. Telson narrowing somewhat towards the posterior border, which is very slightly rounded; the caudal endo- and exopodite are similar in size and form, each has a strong longitudinal ridge; the exopodite is not transversely jointed, and bears a few tubercles.

The limbs from the first to the fifth pair become gradually shorter and more slender. The meropodite of the first pair is flattened, smooth, and has tubercles on the posterior border; the carpopodite is about half the length of the meropodite and carries a few tubercles: the propodite is about three times as long as the carpopodite; in form it is subterete; two rows of tubercles run along the border and unite at the base of the process which represents the fixed finger; a similar row runs from each of the condyles which serve for articulation with the dactylopodite and extends backwards for the distal two thirds of the joint; the space between these rows of tubercles is roughly rugose. Dactylopodite straight, slender, smooth, about half as long as the propodite; the outer edge is flattened, and has two longitudinal rows of minute punctures; sides flat, with similar rows of puncta; dentary border very finely serrate. As throughout the genus, all the limbs are monodactylous, the fixed finger being represented in the two anterior pairs by a short acute process upon which the dactylopodite can be closed. The propodite of the second pair is smooth, and has the widening of the distal end typical of the genus; in length it scarcely exceeds the carpopodite, and it supports a dactylopodite, which has rows of minute puncta and a minutely serrate dentary margin like the first pair.

Measurements. Length of cephalothorax from apex of rostrum to posterior margin 15 millim.; first pair of limbs—combined length of the three proximal joints about 5 millim., meropodite 9, carpopodite 5, propodite 16, dactylopodite 7. In some specimens the propodite is relatively shorter; this may be a sexual difference.

Oxford Clay, St. Ives.

Coll. Mr. George, Northampton, Woodwardian Mus., and my own.

Specimens examined, numerous.

This species is well figured and described by Herm. von Meyer (*Palæontographica*, Bd. i. p. 144, tab. xix.), also by Quenstedt (*Württemb. naturwiss. Jahresh.* 1850, Taf. ii.). It occurs abundantly in the Oxford Clay of St. Ives, Huntingdonshire, but I am not aware that its occurrence in any other British locality has been previously recorded. By reason of the delicacy of the test the specimens invariably occur in an imperfect state. Von Meyer states that it is found in several localities in Germany (Württemberg), frequently associated with *Klytia* (*Eryma*) *Mandelslohi* and a species of *Glyphea*, probably *G. Münsteri*.

M. socialis is readily distinguishable from the other species of the genus by its size and relative proportions; it is most nearly

allied to *M. brevimanus*, Münst. (Solenhofen), but that species is a third larger, and the figure in Oppel (Pal. Mitth. tab. xxii. f. 5) appears to indicate three lateral cephalic ridges; and the propodite, in contradiction of its specific name, is relatively longer than in *M. socialis*. *M. Pearcei*, McCoy, is twice or three times as large, and I fully concur with Dr. Woodward in regarding it as a distinct species.

GONIOCHIRUS CRISTATUS, nov. sp. (Pl. XVI. fig. 9.)

Chelæ short, robust, basal portion of propodite (hand) wider than long; dorsal surface slightly more convex than the palmar; border corresponding with the fixed finger rounded, bearing tubercles, a few of which are scattered over the adjacent portion of both the palmar and dorsal surfaces; the border corresponding with the dactylopodite has a tuberculated "carinal expansion" (Etallon), subtended on each side by a narrow, longitudinal furrow; articular cavity for dactylopodite large, occupying more than half the distal extremity of the hand; carpal articulation large, very oblique. Fingers varying in length from a third to half the length of the hand, both deflected towards the palmar plane; outer border of both fingers flattened, and bearing a series of numerous, crowded, conical tubercles of various sizes; dentary border widening from apex to base, and bearing a row of 6-9 crushing-tubercles near the dorsal edge; palmar and dorsal surfaces of both fingers flattened, smooth (or with a few palmar tubercles), and impressed by large, oval pits for capillary tufts.

I refer these chelæ to a species of *Goniochirus* rather than to a form of the nearly allied genus *Orhomalus*, Etallon, by reason of the large size of the articulation for the dactylopodite, the great obliquity of the carpal articulation, as also the carinal expansion on the border corresponding to the dactylopodite, and the equal degree of convexity of the palmar and the dorsal surfaces of the hand. M. Etallon describes the palmar surface in *Orhomalus* as being flattened and capable of close apposition to the under surface of the carapace, as in the Cryptopods. The specific name applies to the crowded crest of tubercles on the outer borders of the fingers; this character will distinguish this from the only other described species—*G. Babeauvi*, Etal., and *G. Jaccardi*, Etal. The only portions which I have been able to identify are the chelæ; these occur abundantly, but vary considerably in form and size.

Length of hand from carpal base to finger-tip from 20 to 30 millim.; width of hand from 15 to 25 millim.

Oxford Clay, St. Ives.

Coll. Woodwardian, Newcastle, Oxford, Mr. George, and my own. Specimens numerous.

M. Etallon classifies the genus *Goniochirus* among the Brachyura, but suggests the probability that it may be proved, by the discovery of other portions, to be an Anomurous form. If it should be definitely determined to be a true Brachyuran, it would acquire considerable interest as being one of the earliest representatives of that class.

In general form these chelæ resemble those of two Cretaceous

species, *Glyphea Couloni*, Trib., and *G. Meyeri*, Trib., figured and described by M. de Tribolet (Bull. de la Soc. Géol. de France, 3^e sér. t. iii. pl. xv. figs. 2, 4); but the figures of neither of these species indicate the existence of the crest of crowded tubercles on the border of the hand corresponding to the fixed finger.

PSEUDASTACUS, sp. (Pl. XVI. fig. 10.)

Chelæ of first pair elongated; basal portion of propodite (hand) more than twice as long as wide, subcylindrical, surface with minute tubercles, in front of which is a minute depression. Fingers slender, smooth, subterete, probably shorter than the hand (imperfect). Carpopodite short, granulated like the propodite.

In general character these chelæ so closely resemble those of *Pseudastacus*, as figured by Professor Oppel (Pal. Mitth. tab. x. and xi.), that I provisionally refer them to that genus.

Length of hand 9 millim.; width of hand 4 millim.

Coll. Mr. George; Northampton.

Specimens examined 2.

PAGURUS, sp. (Pl. XVI. fig. 11.)

Chelæ of first pair; basal portion of propodite (hand) approximately quadrate in outline, rather longer than wide, dorsal surface slightly convex, smooth, with a few small scattered punctations; a slight longitudinal furrow runs from the base of the dactylopodite to the carpal articulation, which is nearly straight transversely. Palmar surface flattened, smooth. Fingers about as long as hand, nearly equal in size, both deeply pitted by large setigerous puncta, which are most numerous at the apex; dentary borders nearly straight, and bear a series of 6-8 equal-sized tubercles. Carpopodite distinctly tuberculated, and having an oblique longitudinal groove on the proximal moiety. Meropodite smooth laterally, posterior border roughened by tubercles.

Length of chela 14 millim.; width of hand 7 millim.

Coll. Woodwardian Museum.

Specimen examined 1.

PSEUDASTACUS? SERIALIS, nov. sp. (Pl. XVI. fig. 12.)

Propodite elongate, 15 millim. long and 6 millim. wide, subcompressed, ovoid in section; fixed finger about half the length of the hand; dorsal surface of hand with several (5 or 6) longitudinal rows of mamillated tubercles, which are surrounded by tubercles of a much smaller size; the palmar surface bears numerous irregularly disposed tubercles of various sizes, but all smaller than those of the dorsal rows.

Oxford Clay, Fletton, Hunts.

Coll. Alfred N. Leeds, Esq., and Mr. George.

I am unable to refer this pretty chela with certainty to any known genus; but the characters are so well marked as to render specific mention desirable. The name applies to the disposition of the tubercles on the dorsal surface of the hand.

Having described the Huntingdonshire forms, I will briefly notice the only other species which, so far as I am aware, have been recorded as occurring in the Oxford Clay at other localities in Britain:—

Mecochirus Pearcei, *M' Coy.*

Glyphea leptomana, *Phil.*

— *Stricklandi*, *Phil.*

Mecochirus PEARCEI, *M' Coy*, *Ann. & Mag. N. H.* 1849, ser. 2, vol. iv. p. 172. (Pl. XVI. fig. 13.)

I have not been able to ascertain that this species has ever been figured or described in specific detail, probably in consequence of the mutilated condition in which specimens occur, by reason of the delicacy of the test. The carapace is about 25 millim. long; the surface appears to be smooth, but under a strong lens numerous minute puncta are visible. The limbs are better preserved; the first pair, when fully extended, would be about equal to the combined length of the carapace and extended abdomen. In a well-preserved specimen in the Jermyn Street Museum the proximal joints measure 13 millim., meropodite 14 millim., carpopodite 13 millim., propodite 34 millim., dactylopodite 18? millim. The abdominal appendages appear to have been largely developed.

Oxford Clay, Chippenham, Christian Malford, Yorkshire (*Morris's Cat.*).

Coll. The British, Jermyn Street, Woodwardian, and other Museums.

Of this species I have seen perhaps as many as forty specimens, all of them so crushed as to efface most of the minor characters. In general size it is fully twice as large as *M. socialis*, and about equal to *M. Bajeri*, Germ., but considerably smaller than *M. longimanus*, Münster. The first pair of limbs may be distinguished from those of either of the species mentioned by the relative length of the meropodite: in *M. Pearcei* this segment is scarcely longer than the carpopodite; but in *M. Bajeri*, as also in *M. socialis*, it is twice as long, and in *M. longimanus* still longer.

The figure and description published in Mr. Lee's 'Note-book of an Amateur Geologist' (pp. 87, 88, pl. cciv.) as that of *Mecochirus Pearcei* do not apply to that species, but to *Meyeria vectensis*, Bell.

GLYPHEA LEPTOMANA, Phil.

GLYPHEA STRICKLANDI, Phil.

Both these species, mentioned in Mr. Etheridge's edition of Phillip's 'Manual of Geology' as occurring in the Oxford and Kimmeridge Clays, are omitted, and, I think, judiciously, by Dr. Woodward from his Catalogue of British Fossil Crustacea. Of the former species I have not been able to find any figure or description. By the kindness of Professor Prestwich I have examined the specimen of *G. Stricklandi* in the Oxford Museum, figured by Phillip. It consists of a didactylous chela, and cannot be referred

to the monodactylous genus *Glyphea* as at present defined; nor can I assign it with any degree of confidence to its proper genus.

The points of special interest to which I wish to direct attention are:—

1. That the decapod Crustaceans of the Oxford Clay are represented in this country by the occurrence of a larger number of species than had been previously determined. The comparative rarity of this class of fossils in the British rocks contrasts strikingly with their remarkable abundance in a formation of a somewhat later date, the Lithographic Slates of Solenhofen &c. The degree to which this absence implies previous non-existence scarcely admits of determination with our present knowledge of facts.

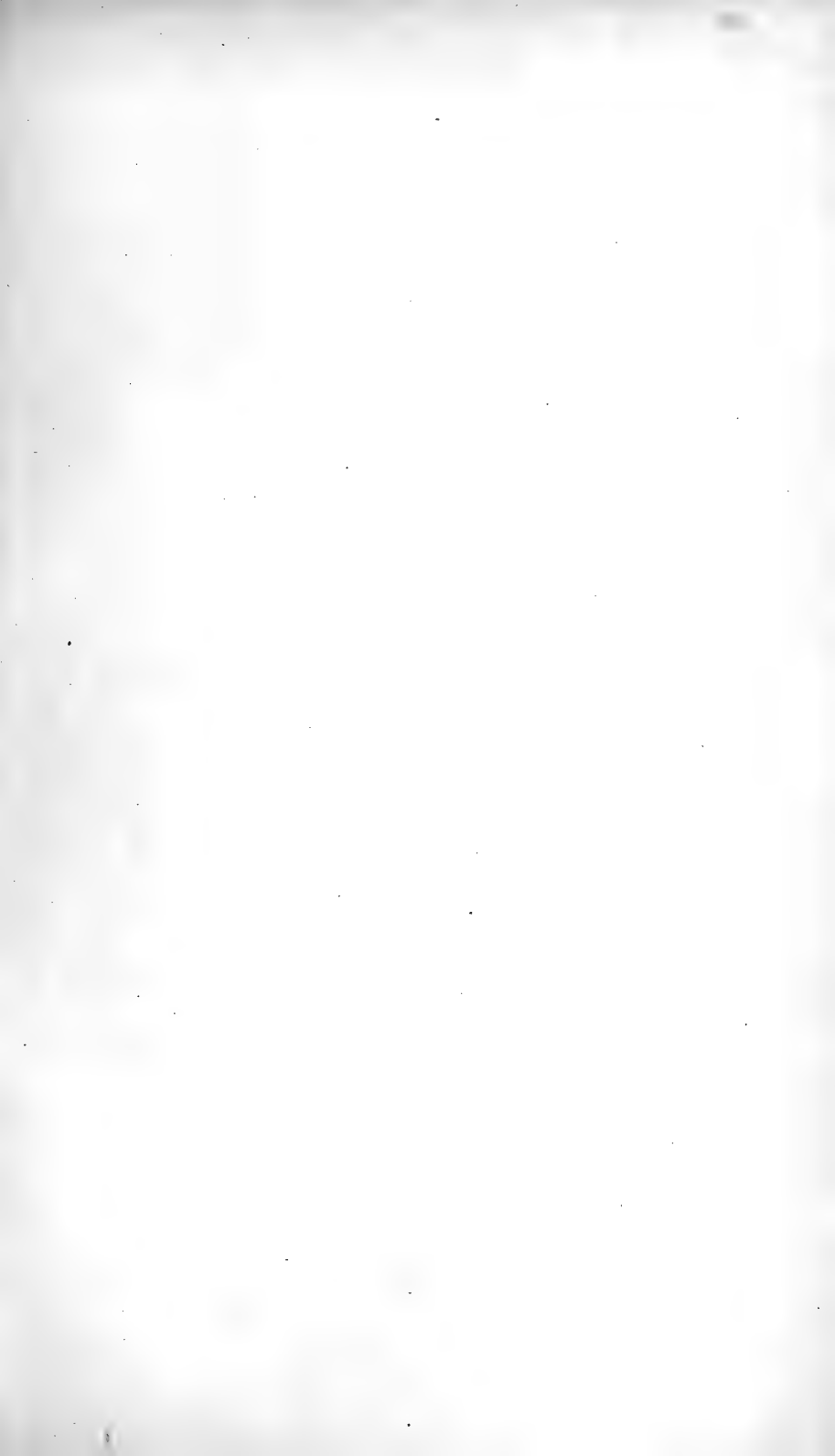
2. That the Oxford-Clay forms belong almost exclusively to the Macrurous type, the Anomura being very scantily represented, and the Brachyura still more so.

This fact is of biological interest as marking a progressive development from the lower to a higher type. The rarity of Brachyura during the Jurassic era contrasts with their preponderance over the Macrura during the Cretaceous period; and they probably outnumber the Macrura existing at the present time in the proportion of three to one. I believe they do not occur at all in the Solenhofen beds, so prolific of the Macrurous forms.

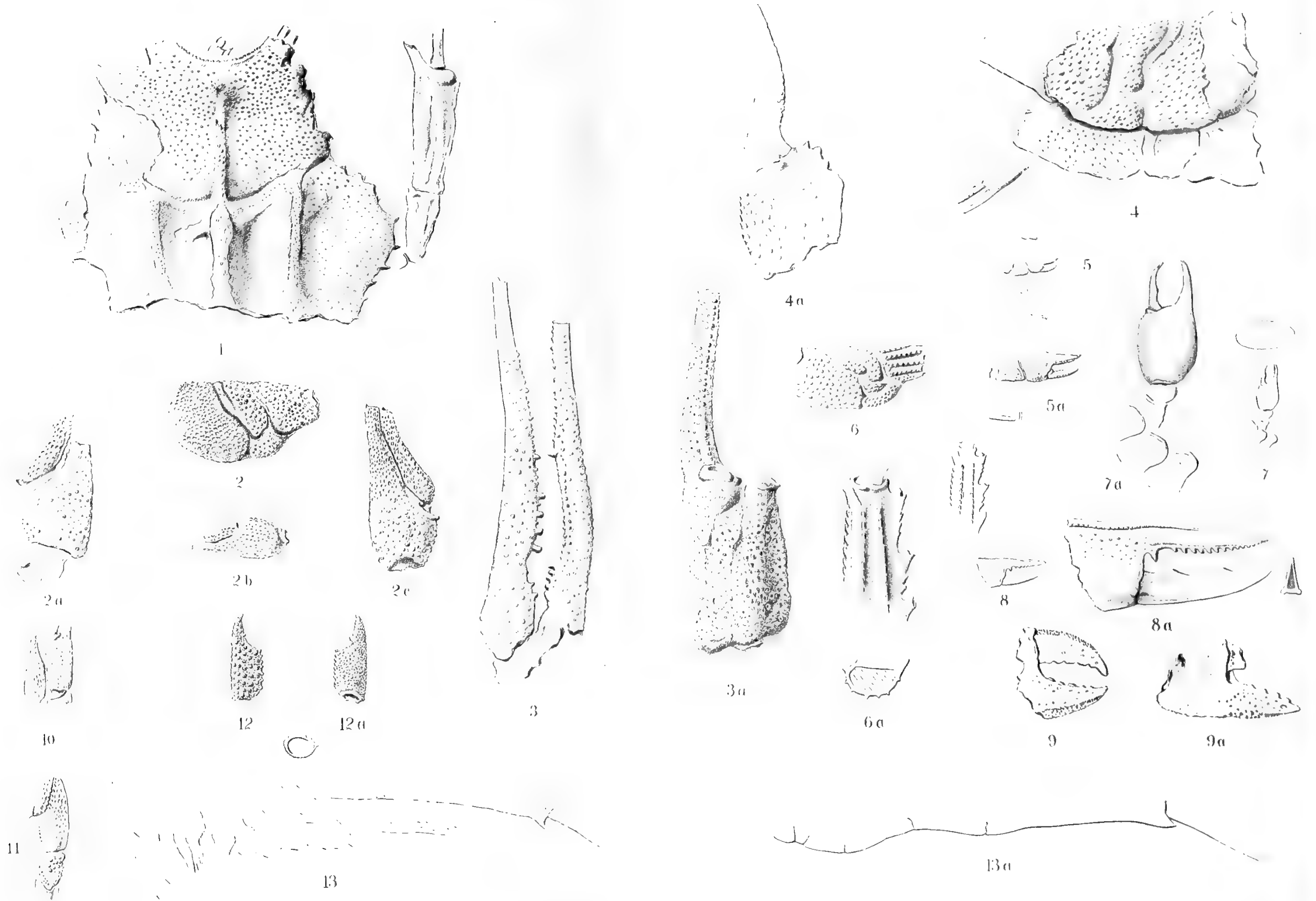
The only species described in this paper which can be referred to the Brachyura is *Goniochirus cristatus*; and M. Etallon suggests that this, as also the allied genus *Orhomalus*, may probably be proved to be Anomurous by the discovery of better-preserved specimens.

EXPLANATION OF PLATE XVI.

- Fig. 1. *Eryon sublevis*, nov. sp. Natural size. St. Ives.
 2. *Eryma Mandelslohi*, Meyer, sp. Nat. size. St. Ives.
 2 a. ———. Chela found *in situ* with the carapace, fig. 2.
 2 b, c. ———. Other forms of chelæ.
 3. ——— *Villersi*, Morière. St. Ives. Dactylopodite and portion of fixed finger of first pair of limbs.
 3 a. ———. Propodite of another specimen.
 4. ——— *Georgii*, nov. sp. Nat. size. St. Ives. Carapace resting on the right first limb, of which the dactyl, propus, carpus, and a portion of the meros are recognizable.
 4 a. ———. Chela of first pair. Nat. size.
 5. ——— *pulchella*, nov. sp. St. Ives. Propodite of first pair and portions of posterior limbs. Nat. size.
 5 a. ———. Enlarged.
 6. *Glyphea hispida*, nov. sp. Nat. size. St. Ives.
 6 a. ———. Distal portion of propodite of first pair. Enlarged and transverse section.
 7. *Magila levimana*, nov. sp. Nat. size. St. Ives.
 7 a. ———. Portions of first pair of limbs and of abdominal segments. Enlarged.
 8. ——— *dissimilis*, nov. sp. Nat. size. St. Ives.
 8 a. ———. Chela and transverse section of dactylopodite. Enlarged view.
 9, 9 a. *Goniochirus cristatus*, nov. sp. St. Ives. Chelæ of first pair of limbs. Nat. size.







- Fig. 10. *Pseudastacus*, sp. St. Ives. First pair of chelæ. Nat. size.
11. *Pagurus*, sp. St. Ives. Portion of first pair of limbs. Nat. size.
12. *Pseudastacus? serialis*, nov. sp. Fletton, Hunts. Propodite of first pair of limbs. Nat. size. (From cabinet of A. N. Leeds, Esq., Eyebury, Peterboro'.)
13. *Mecochirus Pearcei*, M'Coy, sp. Christian Malford. One of the specimens originally determined by Prof. M'Coy (Ann. Nat. Hist. 1849) and now in Woodwardian Museum.
- 13 a. ———. Limb of the first pair. (From a specimen in the Jermyn St. Museum.) Nat. size.

46. *The CASCADE ANTHRACITIC COAL-FIELD of the ROCKY MOUNTAINS, CANADA.* By WM. HAMILTON MERRITT, Esq., F.G.S., Assoc. R.S.M., Memb. American Inst. of Mining Engineers, &c. (Read June 23, 1886.)

THIS Coal-field occurs in the most eastern valley of the Rocky Mountains, the Bow-River valley.

The Cretaceous rocks, which underlie a large area of foot-hills and prairie to the east, have here been caught up and crop out in the bottom of a trough between two parallel rows of mountains, composed of Palæozoic rocks, which rise to a height of about 3000 feet above the river on either side, or some 7000 feet above the sea. The softer shales and sandstones of the Cretaceous rocks have been worn away and form the valley-bottom, and are for the most part covered with gravel from 100 to 200 feet in thickness. The height of the valley above the sea is some 4300 feet.

Both the rocks of the mountains on either side and those of the valley are tilted up and show a dip of between 30° and 40° to the west of south (magnetic) and a strike of from 25° to 30° north of west (magnetic).

Though there are minor local disturbances of the rocks, this dip and strike may be said to be constant throughout the Coal-field.

From palæontological evidence, the age of the Palæozoic rocks is thought by Mr. Whiteaves, Palæontologist to the Geological Survey of Canada, to be of Lower or Sub-Carboniferous, or possibly Devonian age, though probably the former.

The fossils which I collected from these rocks were chiefly Crinoids, *Zaphrentis*, *Spirifera*, and long-winged *Spirifera*.

The rocks are massive Limestones and Dolomites.

The Cretaceous rocks consist of clay shales, black shales, argillaceous sandstone rock, and sandstone. Several Coal-seams have been found about the centre of the trough.

The general section (fig. 1), though not accurately to scale, will suffice to illustrate the occurrence of this trough of Cretaceous Coal-bearing deposits*.

The accompanying sections of the Coal-seams, drawn to scale (fig. 2), were made by me from three exposures of the Coal, which are at some distance from one another.

At the upper exposure "A," there are two seams a quarter of a mile apart, 5 feet and 3 feet thick respectively.

At the centre exposure "B" seven seams are seen, varying from

* At the best exposure of the Coal-seams, where this general section was taken, the unconformity of these Cretaceous rocks is not visible, nor can the faults, which we know must occur, be located, owing to the rocks being, in places, much hidden by overlying gravel. The unconformity of the Cretaceous rocks in the trough is shown at other places at some distance from the section in question, and to attempt to draw in the true folding of the Cretaceous rocks in this part of the trough, or to indicate the exact position of faults I suspect, other than on the east side of the trough, would be entire guess-work.

5 feet to 1 foot in thickness ; and at the lower exposure "C" the two seams to be seen are 10 feet and 12 feet in thickness.

The measures, except at the exposures referred to, are covered up with gravel, as previously mentioned.

The Coal has been altered by metamorphic influence from the lignitic character of the coal occurring in this formation to the east in the plains. It has been changed to an anthracite of a light and free-burning order, which might perhaps be more properly designated a semianthracite. Its specific gravity is 1.4.

A number of analyses have been made of the coal from the various seams, and a fair average of these is well represented in the composition of this coal as given by Mr. Hoffman, of the Canadian Geological Survey, viz. :—

Hygroscopic water	·71
Volatile combustible matter	10·79
Fixed carbon	80·93
Ash	7·57
	100·00

Owing to the great pressure to which these seams have been subjected and the distortion that has accompanied the folding of the beds, the coal, in places, is friable and shows slickensides ; but elsewhere it is of a compact laminated character ; and sometimes, though more rarely, the laminated structure is not apparent in the compact Coal.

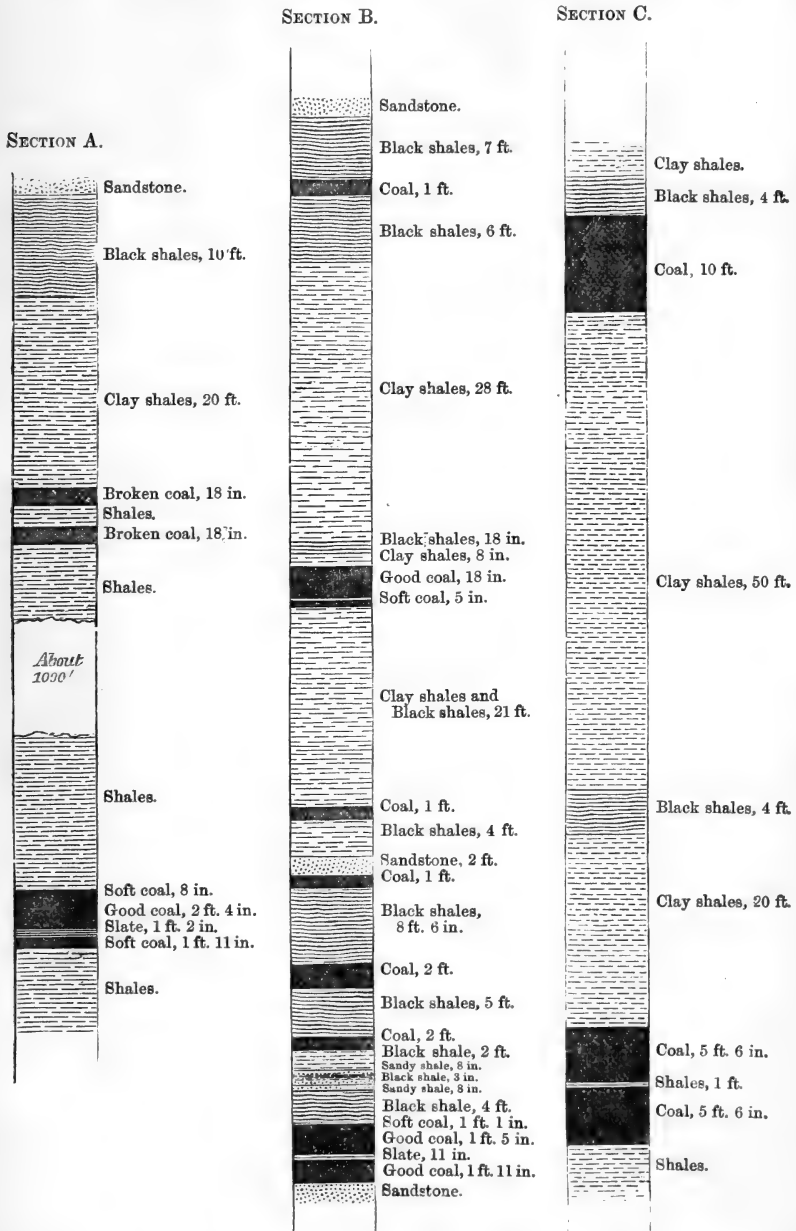
When subjected to a sudden high temperature it slowly breaks into angular fragments without actual decrepitation, and in an ordinary fire it burns with a steady white glow without decrepitation, leaving in either case a white ash.

My examination of this Cascade Anthracitic Coal-region was made last summer. Some of these Coal-seams had been previously visited by Dr. Dawson, of the Geological Survey of Canada, and a few remarks are made about these in the Report of Progress for the years 1882-84. The lower exposure "C" has been since opened up.

As those Fellows of the Geological Society who accompanied the British Association to Canada are aware, lignites occur in the Laramie and Cretaceous formations in places from Manitoba to the Rocky Mountains. The first seam that was opened up was in Manitoba, on the Souris River. This I tested in Winnipeg in 1879, and found it of inferior quality. The following will represent about the average composition of these eastern Lignites :—

	per cent.
Carbon	42
Volatile combustible matter	34
Hygroscopic water.....	16
Ash.....	8
	100

Fig. 2.—Sections through Exposures of Coal-seams, Cascade Coal-field, Rocky Mountains, Canada. (Scale 20 feet to 1 inch.)



As the mountains are approached they influence the quality of the Coal very materially. From a number of specimens collected from outcrops by members of the Geological Survey, Dr. George M. Dawson and Mr. Hoffman suggest three horizons*, represented by districts at varying distances from the mountains or in the mountains.

1. In the prairie to the east, the true Lignites occur, the hygroscopic water ranging from 6 per cent. to 21 per cent., and the fixed carbon varying from 41 per cent. to 55 per cent. They continue to a line about 15 miles from the mountains. Throughout the area to the east of this 15-mile line the rocks are practically horizontal, and for about 100 miles to the east from this line the hygroscopic water is found to increase in a more or less regular ratio of about 1 per cent. for each 10 miles. At the 15-mile line the water-contents of the lignite are put at 5 per cent. Dr. Dawson hesitates to make the influence of pressure wholly responsible for a variation found to extend throughout horizontal beds for more than 100 miles; and as he computes from known variation in the coals that there is about 2 per cent. change in hygroscopic water for every 1000 feet of strata, he thinks a varying thickness of overlying or shore-beds on the mountain coast-line may have been washed away.

2. Between the eastern edge of the mountain (Palæozoic) formation, which is well defined and straight, and the above-mentioned 15-mile line to the east, the foot-hills show evidence of much disturbance and pressure.

Within this area the quality of the lignites approaches that of true coal, the hygroscopic water in them ranging from 1.63 to 6.12 per cent. and the fixed carbon from 50 to 63 per cent.

3. The anthracite or semi-anthracite, occurring in the Cretaceous and Laramie deposits which have been caught up in the Palæozoic rocks of the mountains, is found in long troughs lying in the mountains.

The general section that accompanies this paper shows one of these troughs, and in this case the accompanying coal has been altered into an anthracite, and is, I believe, the only case yet known in Canadian territory where the metamorphic influence has been carried so far in the coals occurring in the above-mentioned formations.

* Report of Progress of Geological Survey of Canada, 1882-84.

47. *On certain EOCENE FORMATIONS of WESTERN SERVIA.* By Dr. A. B. GRIFFITHS, F.R.S.E., F.C.S., &c. (Read June 23, 1886.)

(Communicated by the President.)

[Abridged.]

THE formation described, consisting of shales containing paraffin wax, is met with near the river Golabara, in the west of Servia, and is known to extend over about 30 square miles of country. It forms cliffs rising about 200 feet above the surrounding plains; these show numerous very thin layers of white and grey shale, sometimes separated by thin beds of whitish clay containing rock-salt. The whole geology of the district closely resembles that of the paraffin and salt districts of Galicia. The shales are very rich in paraffin, are entirely free from bituminous impurities, and have no odour. The paraffin in these deposits is probably of vegetable origin *, produced by natural distillation of the old Brown Coals which abound in the vicinity.

On analysis the paraffin shale gave by distillation 2 per cent. of a semisolid hydrocarbon, resembling ozokerite wax, which, when extracted with benzoline, gave 1.75 per cent. of wax. The analysis gave:—

Hydrocarbon (semisolid, distils over at 70° C.)	} 2.00 =	$\left\{ \begin{array}{l} 1.75 \text{ Wax.} \\ 0.25 \text{ Hydrocarbon oils of} \\ \text{the } C_n H_{2n+2} \text{ series.} \end{array} \right.$
Water of combination . . . . .			3.02
Carbonaceous matter containing		
Nitrogen	2.94	(yielding 1.18 Ammonia)
Alumina (Al_2O_3)	30.24	
Iron oxide (Fe_2O_3)	4.79	
Magnesia (MgO)	1.16	
Lime (CaO)	1.11	
Potash (K_2O)	2.00	
Soda (Na_2O)	0.38	
Silica (SiO_2)	52.32	
Loss	0.04	
	100.00	

The old Brown Coals of the vicinity (which contain more or less rhombic iron pyrites, often in rather large macles) gave on analysis:—

* See the author's paper "On the Occurrence of Phenol in *Pinus sylvestris*; a Discovery bearing on the Flora of the Carboniferous Epoch and the Formation of Petroleum," 'Chemical News,' vol. xlix. p. 95; 'Chemiker Zeitung,' vol. viii. p. 342; and 'Berichte der deutschen chemischen Gesellschaft' no. 628, April 1884, p. 171.

	I.	II.
Carbon	49·2	49·3
Hydrogen	1·1	1·2
Water of combination	30·2	30·5
Water, hygroscopic	19·5	19·0
	<hr/>	<hr/>
	100·0	100·0

The quantity of ash amounts to between 5 and 7 per cent. ; it consists chiefly of alumina, magnesia, lime, iron-oxide, and silica.

The argillaceous deposits of the neighbourhood, from which the paraffin shales were formed, are evidently of marine origin and contain abundance of fossils belonging to the genera *Ostrea*, *Cerithium*, *Cyrena*, *Nautilus*, and *Voluta*, besides numerous Nummulites and abundance of marine Diatomaceæ, the assemblage indicating an Upper Eocene age. Remains of marine Vertebrata, principally Teleostean and Selachian fishes, also occur in the clays. Eruptive porphyritic and trachytic rocks have been intruded abundantly into these clays. The former gave on analysis :—

Alumina	18·10
Iron-oxide	2·69
Manganous oxide	0·82
Lime	0·36
Magnesia	0·12
Potash	1·23
Soda	0·16
Silica	75·51
	<hr/>
	98·99

The analysis of the trachytic intrusive rock gave :—

Alumina	20·82
Iron-oxide	5·03
Manganous oxide	0·01
Lime	1·98
Magnesia	0·51
Potash	7·03
Soda	3·10
Phosphoric acid	0·03
Silica	61·49
	<hr/>
	100·00

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

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END OF VOL. XLII.

PROCEEDINGS
OF THE
GEOLOGICAL SOCIETY OF LONDON.

SESSION 1885-86.

November 4, 1885.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

Dr. A. G. Nathorst, of Stockholm, was elected a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Premaxillaries and Scalpriform Teeth of a large Extinct Wombat (*Phascolomys curvirostris*, Ow.)." By Sir Richard Owen, K.C.B., F.R.S., F.G.S.

2. "On the Structure and Classificatory Position of some Madreporaria from the Secondary Strata of England and South Wales." By Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.

3. "On the *Astrocenia* of the Sutton Stone of the Infra-Lias of South Wales." By Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.

The following specimens were exhibited:—

The type specimen of *Clausastrœa Pratti*, M.-Edw. & H., from the Society's collection; and a specimen of *Astrocenia gibbosa* from the Sutton Stone, exhibited by Prof. P. Martin Duncan in illustration of his papers.

A photograph of *Dicynodon* from the Triassic Sandstone of Elgin, exhibited by Prof. J. W. Judd.

November 18, 1885.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

Henry M. Ami, Esq., M.A., Assistant Palæontologist, Geological Survey of Canada, Ottawa, and R. Mountford Deeley, Esq., 1 Mill Hill Road, Derby, were elected Fellows of the Society.

The List of Donations to the Library was read.

A specimen of *Astrocoenia gibbosa* was presented to the Museum by Prof. P. Martin Duncan, F.R.S., F.G.S., illustrating his paper read on the 4th inst.

The following communications were read:—

1. "Results of Recent Researches in some Bone-caves in North Wales (Fynnon Beuno and Cae Gwyn)." By Henry Hicks, M.D., F.R.S., F.G.S.; with Notes on the Animal Remains, by W. Davies, Esq., F.G.S., of the British Museum (Nat. History).

2. "On the Occurrence of the Crocodilian Genus *Tomistoma* in the Miocene of the Maltese Islands." By R. Lydekker, Esq., B.A., F.G.S.

3. "Description of the Cranium of a new Species of *Erinaceus* from the Upper Miocene of Oeningen." By R. Lydekker, Esq., B.A., F.G.S.

The following specimens were exhibited:—

Cast of part of the skull of *Tomistoma champsoides* (Owen), exhibited by R. Lydekker, Esq., in illustration of his paper.

Cast of part of the skull of *Phascalomys curvirostris*, Ow., exhibited by Sir R. Owen, K.C.B., in illustration of his paper read on the 4th inst.

Series of specimens of bones &c. from the Cae Gwyn and Fynnon Beuno Caves, exhibited by Dr. H. Hicks, in illustration of his paper.

Recent bones of Horse which have been split and gnawed by Hyænas in the Zoological Society's Gardens, exhibited by Prof. W. Boyd Dawkins.

December 2, 1885.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

Charles Dawson, Esq., Hastings; Francis J. Ede, Esq., Silchar, Cachar, India; Lewis Edmunds, D.Sc. Lond., B.A., LL.B., 8 Grafton Street, Bond Street, W.; Henry A. Gordon, Esq., Department of

Mines, Wellington, New Zealand; George Frederick Harris, Esq., 1 Great George Street, S.W.; Samuel Learoyd, Esq., Sherwood House, Huddersfield; John Main, Esq., 5 Downvale Terrace, Partick, Glasgow; Mansfeldt Henry Mills, Esq., Tapton Grove, Chesterfield; James Radcliffe, Esq., King Street, Dukinfield; Rev. Thomas Randell, M.A., 6 Grandpont Villas, Oxford; Andrew Edmund Castlestuart Stuart, Esq., Ootacamund, India; Tudor Gruffydd Trevor, Esq., Derwyn, Welshpool; and Arthur Smith Woodward, Esq., 183 B King's Road, S.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On some Borings in Kent.—A Contribution to the Deep-seated Geology of the London Basin." By W. Whitaker, Esq., B.A., F.G.S., Assoc. Inst. C.E. (Communicated by permission of the Director-General of the Geological Survey.)

2. "Note on some recent Openings in the Liassic and Oolitic Rocks of Fawler in Oxfordshire, and on the arrangement of those rocks near Charlbury." By F. A. Bather, Esq. (Communicated by Prof. J. Prestwich, F.R.S., F.G.S.)

The following specimens were exhibited:—

Specimens from well-borings, exhibited by W. Whitaker, Esq., in illustration of his paper.

Specimens from the neighbourhood of Fawler, exhibited by F. A. Bather, Esq., in illustration of his paper.

December 16, 1885.

W. CARRUTHERS, Esq., Vice-President, in the Chair.

Charles John Alford, Esq., 35 Dornton Road, Balham, S.W.; Samuel Blows, Esq., B.A., St. Mark's College, Chelsea, S.W.; James Warne Chenhall, Esq., Assoc. M. Inst. C.E., Anaconda, Montana, U.S.; William Farnworth, Esq., Swindon, near Dudley; Paget Henry Cater Fulcher, Esq., Trinity College, Cambridge; and Harold Temple Wills, Esq., B.A., 11 Upper Belgrave Road, Clifton, Bristol, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "Old Sea-beaches at Teignmouth, Devon." By G. Wareing Ormerod, Esq., M.A., F.G.S.

2. "On the Gabbros, Dolerites, and Basalts of Tertiary Age in Scotland and Ireland." By Prof. John W. Judd, F.R.S., Sec. G.S.

The following specimens were exhibited :—

Photographs and specimens, exhibited by G. Wareing Ormerod, Esq., in illustration of his paper.

Rock-specimens and microscopic slides, exhibited by Prof. J. W. Judd, in illustration of his paper.

January 13, 1886.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

George Niven, Esq., Erkingholme, Coolhurst Road, Crouch End, N., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following name of a Fellow of the Society was read out for the first time in conformity with the Bye-laws Sec. VI. B, Art. 6, in consequence of the non-payment of the arrears of his contributions :—R. C. Forster, Esq.

The PRESIDENT said,—It may not be known to all present this evening that during the past week we have lost a well-known member of forty years' standing. Prof. John Morris died last Thursday, and to-day some of us have stood by his grave in Kensal Green Cemetery. The Society has lost its most learned member, and many of us have been deprived of a very dear friend.

The following communications were read :—

1. "On some Fish-remains from the Tertiary Strata of New Zealand." By James W. Davis, Esq., F.G.S.

[Abstract*.]

A number of fossil fish-remains from Tertiary beds in New Zealand have been forwarded to the author by Captain F. W. Hutton, and were described in the present paper. The forms of which descriptions were given are two new species of *Lamna*, *Carcharodon angustidens*, Agassiz, and a new *Carcharodon*, one new species of *Notidanus*, one of *Myliobatis*, and one referred to *Sparnodus*. All

* This paper has been withdrawn by permission of the Council.

the above were founded on teeth. A vertebra of *Lamna* and a fish-spine were also described, and the collection contained a specimen regarded by the author as a fragment of a Reptilian tooth.

DISCUSSION.

Prof. SEELEY remarked that it was difficult to speak about such specimens as were exhibited in illustration of this paper without a more careful study of them. The specimens presented a very striking resemblance to well-known European forms, and in fact it seems doubtful whether specific names should be given to forms so imperfectly known. As regarded the new species of *Myliobatis*, even when we had the whole palate of a Ray, it was by no means an easy matter to determine it specifically, and a single tooth was insufficient for such a purpose. The specimens referred to the genus *Notidanus* seemed to him to show important differences from the known forms of the genus.

He thought that the most interesting of all the specimens exhibited was that which the Author had rightly regarded as Reptilian. Unfortunately the specimen was very imperfect,—there was less than half the crown present, and no fang. This specimen was especially interesting as bearing a decided resemblance to Reptilian teeth of Cretaceous age; from its imperfect state its affinities were certainly dubious, but its characters seemed to suggest a Mosasaurian type. The occurrence of this tooth may therefore be an indication of the survival of a Mesozoic type into Tertiary times.

Mr. SMITH WOODWARD inquired whether the Author had referred to Mr. Lawley's Italian work on *Carcharodon*, which would suggest no specific difference between the two specimens exhibited. The *Notidanus* was a typical upper tooth. He also inquired how the author's *Lamna plicata* differed from *L. contortidens* of South Carolina and Europe.

The AUTHOR thanked Prof. Seeley for his remarks. In reply to Mr. Woodward he stated that he was not acquainted with the North-American *Lamna* mentioned by him.

2. "On a recent Section through Walton Common, exposing the London Clay, Bagshot Beds, and Plateau-gravel." By W. H. Hudleston, Esq., F.R.S., F.G.S.

The following specimens were exhibited:—

Quartzite boulder, weight about 14 lbs., found in a Coal-seam, Cannock and Rugeley Colliery (Geol. Mag. 1873, p. 289), exhibited by the President.

Specimens of fossil Fish-teeth and spines, from New Zealand, exhibited by J. W. Davis, Esq., F.G.S., in illustration of his paper.

Specimens of Sands, Flints, Chert, &c., exhibited by W. H. Hudleston, Esq., F.R.S., F.G.S., in illustration of his paper.

January 27, 1886.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

H. Kirby Atkinson, Esq., 89 Camberwell New Road, S.E., was elected a Fellow, and Professor Gustav Tschermak of Vienna, a Foreign Member of the Society.

The List of Donations to the Library was read.

The following name of a Fellow of the Society was read out for the second time in conformity with the Bye-laws Sec. VI. B, Art. 6, in consequence of the non-payment of the arrears of his contributions:—R. C. Forster, Esq.

The following communications were read:—

1. "On the Fossil Mammalia of Maragha, in North-western Persia." By R. Lydekker, Esq., B.A., F.G.S., &c.

2. "On the Pliocene of Maragha, Persia, and its resemblance to that of Pikermi, in Greece; on Fossil Elephant-remains of Caucasia and Persia; and on the results of a Monograph of the Fossil Elephants of Germany and Italy." By Dr. H. Pohlig. Communicated by Dr. G. J. Hinde, F.G.S.

3. "The Thames-valley Surface-deposits of the Ealing District, and their associated Palæolithic Floors." By John Allen Brown, Esq., F.R.G.S. Communicated by A. Ramsay, Esq., F.G.S.

The following specimens were exhibited:—

Fossil bones and Palæolithic flints, from Ealing, Hanwell, &c., exhibited by J. Allen Brown, Esq., in illustration of his paper.

February 10, 1886.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

Walter Joseph Baker, Esq., 160 A Southwark Bridge Road, S.E.; Robert Law, Esq., Hollingworth, Walsden, Todmorden; William Stert Milnes, Esq., Woodstock, Grove Park, Lee, S.E.; and Edward John Silcock, Esq., 1 Ridge Mount, Cliff Road, Leeds, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On a new Species of *Psilotites* from the Lanarkshire Coal-field." By R. Kidston, Esq., F.G.S.*

2. "The Melbourn Rock and the Zone of *Belemnitella plena*, from Cambridge to the Chiltern Hills." By W. Hill, Esq., F.G.S., and A. J. Jukes-Browne, Esq., F.G.S.

* This paper has been withdrawn by permission of the Council.

3. "On the Beds between the Upper and Lower Chalk of Dover, and their comparison with the Middle Chalk of Cambridgeshire." By W. Hill, Esq., F.G.S.

The following specimens were exhibited:—

Rock-specimens and microscopic rock-sections, exhibited by Wm. Hill, Esq., in illustration of his and Mr. Jukes-Browne's papers.

Six specimens from the Streatham boring, from depths between 463 and 840 feet, exhibited by W. Whitaker, Esq., B.A., F.G.S.

Photographs of New-Zealand Geysers, hot-springs, and sinter-ter-races, taken by Josiah Martin, Esq., F.G.S., exhibited by Prof. J. W. Judd, F.R.S., F.G.S.

With regard to these photographs Prof. Judd spoke as follows:—

Mr. Josiah Martin, F.G.S., has sent for exhibition a series of photographs illustrating the geyser-eruptions and the sinter-ter-races of New Zealand. These photographs have been obtained by Mr. Martin during an expedition especially undertaken by him for the purpose of studying the interesting phenomena of the volcanic band in the North Island.

By the application of the method of *instantaneous* photography, Mr. Martin has been able to show that during the eruption of some of the geysers a curious *explosive action* takes place, which has not hitherto been observed. The body of heated water, after its rise from the geyser-tube, is seen to be violently dispersed, probably by a sudden liberation of high-pressure steam. Several of the photographs now exhibited illustrate this remarkable phenomenon in a very striking manner.

ANNUAL GENERAL MEETING,

February 19, 1886.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair

REPORT OF THE COUNCIL FOR 1885.

In presenting their Report for the year 1885, it is with much pleasure that the Council of the Geological Society find themselves able to lay before the Society a statement of affairs rather more cheering than those that they have been under the necessity of bringing forward for some years past. Both financially and as regards the number of Fellows, the position of the Society is decidedly better than at the last Anniversary Meeting.

The number of Fellows elected during the year is 54, of whom 40 paid their fees before the end of the year, making, with 11 previously elected Fellows who paid their fees in 1885, a total accession during the year of 51 Fellows. Against this we have to set the loss by death of 27 Fellows, and by resignation of 16 Fellows, while 3 Fellows were removed from the list for non-payment of contributions, making a total loss of 46 Fellows. There is thus an actual increase of 5 in the number of Fellows of the Society. Of the 27 Fellows deceased 7 were compounders, and 9 non-contributing Fellows; the number of contributing Fellows is increased by 15, being now 831.

The total number of Fellows, Foreign Members, and Foreign Correspondents was 1420 at the end of the year 1884, and 1425 at the close of 1885.

In 1885 intelligence was received of the decease of 2 Foreign Members, and one of the vacancies so caused was filled up during the year. The list of Foreign Correspondents showed 2 vacancies at the end of 1884, and intelligence was received in 1885 of the decease of another Foreign Correspondent. These losses, with the filling up of the vacancy in the list of Foreign Members, caused, in all, 4 vacancies among the Foreign Correspondents of the Society, 3 of which were filled up within the year. Thus at the close of the year 1885, there was one vacancy in the list of Foreign Members, and one in that of Foreign Correspondents.

The total Receipts on account of Income for the year 1885 were £2663 6s. 1*d.*, being £82 0s. 1*d.* more than the estimated Income for the year. The total Expenditure, on the other hand, was only £2315 7s. 11*d.*, or £264 8s. 1*d.* less than the estimated Expenditure for the year. The excess of the Income over the Expenditure of the year was £347 18s. 2*d.*

The Council have to announce the completion of Vol. XLI. and the commencement of Vol. XLII. of the Society's Quarterly Journal.

The Council have also to announce that a Portrait by the late H. W. Pickersgill, R.A., of the late Sir Henry T. De la Beche has been kindly presented to the Society by the President.

The Council have awarded the Wollaston Medal to Professor A. L. O. Des Cloizeaux, of Paris, Member of the Institute of France, For.M.G.S., in recognition of the value of his Mineralogical researches, especially in connexion with the Crystallographic and Optical Characters of Minerals, which, by supplying a secure foundation to Petrology, have contributed so largely to the advance of Geological Science.

The Murchison Medal, with the sum of Ten Guineas from the proceeds of the Fund, has been awarded to William Whitaker, Esq., B.A., F.G.S., in testimony of appreciation of the services which he has rendered to Geology, especially by his original researches among the Cretaceous and Tertiary Rocks of the South-east of England, and by his work in connexion with the Bibliography of the Science.

The Lyell Medal, with the sum of Twenty Guineas from the proceeds of the Fund, has been awarded to William Pengelly, Esq., F.R.S., F.G.S., in recognition of the value of his researches in connexion with the Geology of Devonshire, and especially with regard to the early history of Man in that region.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to John Starkie Gardner, Esq., F.G.S., as a mark of appreciation of his investigations upon the Tertiary Fossil Floras of this country, and to assist him in the further prosecution thereof.

The balance of the proceeds of the Murchison Geological Fund has been awarded to Clement Reid, Esq., F.G.S., in recognition of the value of his researches among the Pliocene and Glacial Deposits of East Anglia, and to aid him in further inquiries of a like kind.

The balance of the proceeds of the Lyell Geological Fund has been awarded to Daniel Mackintosh, Esq., F.G.S., in testimony of appreciation of his extensive and long-continued studies of the Glacial and other Superficial Deposits of the north-west of England, and to assist him in further investigations.

The sum of Twenty Guineas from the Proceeds of the Barlow-Jameson Fund has been awarded to Dr. H. J. Johnston-Lavis, F.G.S., in recognition of the value of his researches upon the Volcanic and Seismic Phenomena of Southern Italy, and to aid him in still carrying on his inquiries.

REPORT OF THE LIBRARY AND MUSEUM COMMITTEE.

Library.

Since the last Anniversary Meeting a great number of valuable additions have been made to the Library, both by donation and by purchase.

As Donations the Library has received about 150 volumes of separately published works and Survey Reports, and about 423 Pamphlets and separate impressions of Memoirs, besides about 144 volumes and 121 detached parts of the publications of various Societies, 16 volumes of current Periodicals, presented by their respective Editors, and twelve volumes of Newspapers. A nearly complete set, consisting of 27 volumes, of the 'Zeitschrift für Berg-, Hütten- und Salinenwesen' was also presented to the Library. This will constitute a total addition to the Society's Library, by donation, of about 469 volumes and 423 pamphlets.

A considerable number of Maps, Plans, and Charts have been added to the Society's collections by presentation. They amount altogether to 827 sheets, large and small, of which 697 sheets were received from the Ordnance Survey of Great Britain. Of the remainder, 15 sheets are from the French Dépôt de la Marine, 61 from the Geological Survey of Great Britain, 16 from that of Saxony, 10 from that of Belgium, 6 from the Roumanian Geological Survey, 5 each from the Geological Surveys of Sweden and Norway, 3 from that of Switzerland, and 4 from the Russian Geological Committee. From individual Donors the Society has also received 4 sheets of Favre's map of the Alpine Glaciers, and a Geological Map of Berlin.

The books and maps above referred to have been received from 188 personal Donors, the Editors or Publishers of 15 Periodicals, and 168 Societies, Surveys, and other Public Bodies, making in all 371 Donors.

By Purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 31 volumes of Books, and of 50 parts (making about 14 volumes) of various Periodicals, besides 22 parts of certain works published serially. The Society has also purchased 4 sheets of the Government Geological Survey Map of France, and 10 sheets of the smaller Geological Map of France issued by MM. Vasseur and Carez.

The cost of Books, Periodicals, and Maps purchased during the year 1885 was £52 18s 2d., and of Binding £59 1s. 7d., making a total of £111 19s. 9d.

Museum.

The Collections in the Museum remain in much the same condition as at the date of the last Report of the Committee.

The Donations to the Museum during the year 1885 were not numerous; they consist of a specimen of Fulgurite from Mont Blanc, presented by F. Rutley, Esq., F.G.S.; ten specimens of sand-worn stones from Hokitika, New Zealand, presented by W. D. Campbell, Esq., F.G.S.; six slides of Cyclostomatous Bryozoa, from Muddy Creek, South Australia, presented by J. Bracebridge Wilson, Esq., of Geelong; and a specimen of *Astrocœnia gibbosa*, Duncan, from the Sutton Stone, presented by Prof. P. Martin Duncan, M.B., F.R.S., F.G.S., being the specimen figured in his paper in the Quarterly Journal (vol. xlii. pl. viii.).

COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE
CLOSE OF THE YEARS 1884 AND 1885.

	Dec. 31, 1884.	Dec. 31, 1885.
Compounders	313	312
Contributing Fellows.....	816	831
Non-contributing Fellows..	213	204
	<hr/>	<hr/>
	1342	1347
Foreign Members	40	39
Foreign Correspondents....	38	39
	<hr/>	<hr/>
	1420	1425

*Comparative Statement explanatory of the Alterations in the Number
of Fellows, Foreign Members, and Foreign Correspondents at the
close of the years 1884 and 1885.*

Number of Compounders, Contributing and Non- contributing Fellows, December 31, 1884	}	1342		
Add Fellows elected during former year and paid in 1885			}	11
Add Fellows elected and paid in 1885 .....					40
		<hr/>	1393	
<i>Deduct</i> Compounders deceased		7		
Contributing Fellows deceased		11		
Non-contributing Fellows deceased		9		
Contributing Fellows resigned		16		
Contributing Fellows removed		3		
		<hr/>	46	
			<hr/>	
			1347	
Number of Foreign Members, and Foreign Correspondents, December 31, 1884	}	78		
<i>Deduct</i> Foreign Members deceased ..			2	
Foreign Correspondent deceased ..	1			
Foreign Correspondent elected } Foreign Member	}	1		
			<hr/>	4
			<hr/>	
			74	
Add Foreign Member elected		1		
Foreign Correspondents elected		3		
		<hr/>	78	
			<hr/>	
			<u>1425</u>	

DECEASED FELLOWS.

Compounders (7).

Barlow, P. W., Esq.
 Bilke, E., Esq.
 Campbell, J. F., Esq.
 Hawes, W., Esq.

Leighton, W. H., Esq.
 Peacock, R. A., Esq.
 Selkirk, Earl of.

Resident and other Contributing Fellows (11).

Carpenter, Dr. W. B.
 Davidson, Dr. T.
 Davies, D. C., Esq.
 Dunning, J., Esq.
 Evans, D. T., Esq.
 Humbert, C. F., Esq.

Jeffreys, Dr. J. G.
 Johnson, H., Esq.
 Plews, H. T., Esq.
 Ratcliff, C., Esq.
 Stutchbury, E., Esq.

Non-contributing Fellows (9).

Baker, J. L. B., Esq.
 Caley, J. A., Esq.
 Lindsay, C., Esq.
 Still, H., Esq.
 Thurtell, Rev. A.

Wyatt, J., Esq.
 Bull, Rev. J.
 Collings, Rev. W. T.
 Worsley, Rev. J.

Foreign Members (2).

Helmersen, Gen. G. von.

Milne-Edwards, Dr. H.

Foreign Correspondent (1).

Ponzi, Prof. G.

Fellows Resigned (16).

Adams, Dr. G. E. D'Arcy.
 Anderson, R., Esq.
 Clark, J. E., Esq.
 Comerford-Casey, G. E., Esq.
 Davey, E. C., Esq.
 Dawes, G., Esq.
 Dixon, Rev. R.
 Farie, J., Esq.

Gardner, R. P., Esq.
 Griffith, Rev. H.
 Jackson, H. W., Esq.
 Keeping, W., Esq.
 Rivett-Carnac, J. H., Esq.
 Rose, Dr. H. C.
 T aft, Rev. J. R.
 Tremlett, Rear-Adm. F. S.

Fellows Removed (3).

Bock, C., Esq.
Gasking, Rev. S.

| Low, W., Esq.

The following Personage was elected from the List of Foreign Correspondents to fill a vacancy in the List of Foreign Members during the year 1885.

Professor Jules Gosselet of Lille.

The following Personages were elected Foreign Correspondents during the year 1885.

M. F. Fouqué of Paris.
Professor G. Lindström of Stockholm.
Dr. A. G. Nathorst of Stockholm.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Professor T. G. Bonney, retiring from the office of President.

That the thanks of the Society be given to W. Carruthers, Esq., and J. W. Hulke, Esq., retiring from the office of Vice-President.

That the thanks of the Society be given to Professor J. W. Judd, retiring from the office of Secretary.

That the thanks of the Society be given to W. Carruthers, Esq., Professor Boyd Dawkins, the Rev. E. Hill, J. W. Hulke, Esq., and the Rev. H. H. Winwood, retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year :—

OFFICERS.

PRESIDENT.

Prof. J. W. Judd, F.R.S.

VICE-PRESIDENTS.

H. Bauerman, Esq.
 John Evans, D.C.L., LL.D., F.R.S.
 Archibald Geikie, LL.D., F.R.S.
 J. A. Phillips, Esq., F.R.S.

SECRETARIES.

W. T. Blanford, LL.D., F.R.S.
 W. H. Hudleston, Esq., M.A., F.R.S.

FOREIGN SECRETARY.

Warrington W. Smyth, Esq., M.A., F.R.S.

TREASURER.

Prof. T. Wiltshire, M.A., F.L.S.

COUNCIL.

H. Bauerman, Esq.	T. McKenny Hughes, M.A.
W. T. Blanford, LL.D., F.R.S.	Prof. T. Rupert Jones, F.R.S.
Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.	Prof. J. W. Judd, F.R.S.
Thomas Davies, Esq.	R. Lydekker, Esq., B.A.
Prof. P. M. Duncan, M.B. Lond., F.R.S.	J. E. Marr, Esq., M.A.
John Evans, D.C.L., LL.D., F.R.S.	J. A. Phillips, Esq., F.R.S.
A. Geikie, LL.D., F.R.S.	Prof. H. G. Seeley, F.R.S.
Henry Hicks, M.D., F.R.S.	W. W. Smyth, Esq., M.A., F.R.S.
G. J. Hinde, Ph.D.	J. J. H. Teall, Esq., M.A.
John Hopkinson, Esq.	William Topley, Esq.
W. H. Hudleston, Esq., M.A., F.R.S.	Prof. T. Wiltshire, M.A., F.L.S.
	H. Woodward, LL.D., F.R.S.

LIST OF
THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1885.

Date of Election.	
1827.	Dr. H. von Dechen, <i>Bonn.</i>
1848.	James Hall, Esq., <i>Albany, State of New York.</i>
1850.	Professor Bernhard Studer, <i>Berne.</i>
1851.	Professor James D. Dana, <i>New Haven, Connecticut.</i>
1851.	General G. von Helmersen, <i>St. Petersburg. (Deceased.)</i>
1853.	Count Alexander von Keyserling, <i>Rayküll, Russia.</i>
1853.	Professor L. G. de Koninck, <i>Liège.</i>
1856.	Professor Robert Bunsen, For. Mem. R.S., <i>Heidelberg.</i>
1857.	Professor H. B. Geinitz, <i>Dresden.</i>
1857.	Dr. Hermann Abich, <i>Vienna.</i>
1859.	Dr. Ferdinand Römer, <i>Breslau.</i>
1860.	Dr. H. Milne-Edwards, For. Mem. R.S., <i>Paris. (Deceased.)</i>
1864.	M. Jules Desnoyers, <i>Paris.</i>
1866.	Dr. Joseph Leidy, <i>Philadelphia.</i>
1867.	Professor A. Daubrée, For. Mem. R.S., <i>Paris.</i>
1871.	Dr. Franz Ritter von Hauer, <i>Vienna.</i>
1874.	Professor Alphonse Favre, <i>Geneva.</i>
1874.	Professor E. Hébert, <i>Paris.</i>
1874.	Professor Albert Gaudry, <i>Paris.</i>
1875.	Professor Fridolin Sandberger, <i>Würzburg.</i>
1875.	Professor Theodor Kjerulf, <i>Christiania.</i>
1875.	Professor F. August Quenstedt, <i>Tübingen.</i>
1876.	Professor E. Beyrich, <i>Berlin.</i>
1877.	Dr. Carl Wilhelm Gümbel, <i>Munich.</i>
1877.	Dr. Eduard Suess, <i>Vienna.</i>
1879.	Dr. F. V. Hayden, <i>Washington.</i>
1879.	Major-General N. von Kokscharow, <i>St. Petersburg.</i>
1879.	M. Jules Marcou, <i>Cambridge, U. S.</i>
1879.	Dr. J. J. S. Steenstrup, For. Mem. R.S., <i>Copenhagen.</i>
1880.	Professor Gustave Dewalque, <i>Liège.</i>
1880.	Baron Adolf Erik Nordenskiöld, <i>Stockholm.</i>
1880.	Professor Ferdinand Zirkel, <i>Leipzig.</i>
1882.	Professor Sven Lovén, <i>Stockholm.</i>
1882.	Professor Ludwig Rüttimeyer, <i>Basle.</i>
1883.	Professor J. S. Newberry, <i>New York.</i>
1883.	Professor Otto Martin Torell, <i>Stockholm.</i>
1884.	Professor G. Capellini, <i>Bologna.</i>
1884.	Professor A. L. O. Des Cloizeaux, For. Mem. R.S., <i>Paris.</i>
1884.	Professor G. Meneghini, <i>Pisa.</i>
1884.	Professor J. Szabó, <i>Pesth.</i>
1885.	Professor Jules Gosselet, <i>Lille.</i>

LIST OF
THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1885.

Date of
Election.

1863. Count A. G. Marschall, *Vienna*.
 1863. Professor Giuseppe Ponzi, *Rome*. (*Deceased*).
 1863. Dr. F. Senft, *Eisenach*.
 1864. Dr. Charles Martins, *Montpellier*.
 1866. Professor J. P. Lesley, *Philadelphia*.
 1866. Professor Victor Raulin, *Bordeaux*.
 1866. Baron Achille de Zigno, *Padua*.
 1872. Herr Dionys Stur, *Vienna*.
 1872. Professor J. D. Whitney, *Cambridge, U. S.*
 1874. Professor Iginò Cocchi, *Florence*.
 1874. M. Gustave H. Cotteau, *Auxerre*.
 1874. Professor G. Seguenza, *Messina*.
 1874. Dr. T. C. Winkler, *Haarlem*.
 1875. Professor Gustav Tschermak, *Vienna*.
 1877. Professor George J. Brush, *New Haven*.
 1877. Professor E. Renevier, *Lausanne*.
 1877. Count Gaston de Saporta, *Aix-en-Provence*.
 1879. Professor Pierre J. van Beneden, For. Mem. R.S., *Louvain*.
 1879. M. Édouard Dupont, *Brussels*.
 1879. Professor Guglielmo Guiscardi, *Naples*.
 1879. Professor Gerhard Vom Rath, *Bonn*.
 1879. Dr. Émile Sauvage, *Paris*.
 1880. Professor Luigi Bellardi, *Turin*.
 1880. Professor Leo Lesquereux, *Columbus*.
 1880. Dr. Melchior Neumayr, *Vienna*.
 1880. M. Alphonse Renard, *Brussels*.
 1881. Professor E. D. Cope, *Philadelphia*.
 1882. Professor Louis Lartet, *Toulouse*.
 1882. Professor Alphonse Milne-Edwards, *Paris*.
 1883. M. François Leopold Cornet, *Mons*.
 1883. Baron Ferdinand von Richthofen, *Leipzig*.
 1883. Professor Karl Alfred Zittel, *Munich*.
 1884. Dr. Charles Barrois, *Lille*.
 1884. M. Alphonse Briart, *Morlanwelz*.
 1884. Professor Hermann Credner, *Leipzig*.
 1884. Baron C. von Ettingshausen, *Gratz*.
 1884. Dr. E. Mojsisovics von Mojsvár, *Vienna*.
 1885. M. F. Fouqué, *Paris*.
 1885. Professor G. Lindström, *Stockholm*.
 1885. Dr. A. G. Nathorst, *Stockholm*.

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

- | | |
|-------------------------------------|-----------------------------------|
| 1831. Mr. William Smith. | 1859. Mr. Charles Darwin. |
| 1835. Dr. G. A. Mantell. | 1860. Mr. Searles V. Wood. |
| 1836. M. Louis Agassiz. | 1861. Professor Dr. H. G. Bronn. |
| 1837. } Capt. T. P. Cautley. | 1862. Mr. R. A. C. Godwin-Austen. |
| } Dr. H. Falconer. | 1863. Professor Gustav Bischof. |
| 1838. Sir Richard Owen. | 1864. Sir R. I. Murchison. |
| 1839. Professor C. G. Ehrenberg. | 1865. Dr. Thomas Davidson. |
| 1840. Professor A. H. Dumont. | 1866. Sir Charles Lyell. |
| 1841. M. Adolphe T. Brongniart. | 1867. Mr. G. Poulett Scrope. |
| 1842. Baron L. von Buch. | 1868. Professor Carl F. Naumann, |
| 1843. } M. Elie de Beaumont. | 1869. Dr. H. C. Sorby. |
| } M. P. A. Dufrénoy. | 1870. Professor G. P. Deshayes. |
| 1844. Rev. W. D. Conybeare. | 1871. Sir A. C. Ramsay. |
| 1845. Professor John Phillips. | 1872. Professor J. D. Dana. |
| 1846. Mr. William Lonsdale. | 1873. Sir P. de M. Grey-Egerton. |
| 1847. Dr. Ami Boué. | 1874. Professor Oswald Heer. |
| 1848. Rev. Dr. W. Buckland. | 1875. Professor L. G. de Koninck. |
| 1849. Professor Joseph Prestwich. | 1876. Professor T. H. Huxley. |
| 1850. Mr. William Hopkins. | 1877. Mr. Robert Mallet. |
| 1851. Rev. Prof. A. Sedgwick. | 1878. Dr. Thomas Wright. |
| 1852. Dr. W. H. Fitton. | 1879. Professor Bernhard Studer. |
| 1853. } M. le Vicomte A. d'Archiac. | 1880. Professor Auguste Daubrée. |
| } M. E. de Verneuil. | 1881. Professor P. Martin Duncan. |
| 1854. Sir Richard Griffith. | 1882. Dr. Franz Ritter von Hauer. |
| 1855. Sir H. T. De la Beche. | 1883. Dr. W. T. Blanford. |
| 1856. Sir W. E. Logan. | 1884. Professor Albert Gaudry. |
| 1857. M. Joachim Barrande. | 1885. Mr. George Busk. |
| 1858. } Herr Hermann von Meyer. | 1886. Professor A. L. O. Des |
| } Mr. James Hall. | Cloizeaux. |

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON

"DONATION-FUND."

1831. Mr. William Smith.	1860. } Professor T. Rupert Jones.
1833. Mr. William Lonsdale.	} Mr. W. K. Parker.
1834. M. Louis Agassiz.	1861. Professor A. Daubrée.
1835. Dr. G. A. Mantell.	1862. Professor Oswald Heer.
1836. Professor G. P. Deshayes.	1863. Professor Ferdinand Senft.
1838. Sir Richard Owen.	1864. Professor G. P. Deshayes.
1839. Professor C. G. Ehrenberg.	1865. Mr. J. W. Salter.
1840. Mr. J. De Carle Sowerby.	1866. Dr. Henry Woodward.
1841. Professor Edward Forbes.	1867. Mr. W. H. Baily.
1842. Professor John Morris.	1868. M. J. Bosquet.
1843. Professor John Morris.	1869. Mr. W. Carruthers.
1844. Mr. William Lonsdale.	1870. M. Marie Rouault.
1845. Mr. Geddes Bain.	1871. Mr. R. Etheridge.
1846. Mr. William Lonsdale.	1872. Dr. James Croll.
1847. M. Alcide d'Orbigny.	1873. Professor J. W. Judd.
1848. } Cape-of-Good-Hope Fossils.	1874. Dr. Henri Nyst.
} M. Alcide d'Orbigny.	1875. Mr. L. C. Miall.
1849. Mr. William Lonsdale.	1876. Professor Giuseppe Seguenza.
1850. Professor John Morris.	1877. Mr. R. Etheridge, Jun.
1851. M. Joachim Barrande.	1878. Professor W. J. Sollas.
1852. Professor John Morris.	1879. Mr. S. Allport.
1853. Professor L. G. de Koninck.	1880. Mr. Thomas Davies.
1854. Dr. S. P. Woodward.	1881. Dr. R. H. Traquair.
1855. Drs. G. and F. Sandberger.	1882. Dr. G. J. Hinde.
1856. Professor G. P. Deshayes.	1883. Mr. John Milne.
1857. Dr. S. P. Woodward.	1884. Mr. E. Tulley Newton.
1858. Mr. James Hall.	1885. Dr. Charles Callaway.
1859. Mr. Charles Peach.	1886. Mr. J. S. Gardner.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

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|--|---|
| 1873. Mr. William Davies. <i>Medal.</i> | 1880. Mr. R. Etheridge. <i>Medal.</i> |
| 1873. Professor Oswald Heer. | 1881. Professor A. Geikie. <i>Medal.</i> |
| 1874. Dr. J. J. Bigsby. <i>Medal.</i> | 1881. Mr. F. Rutley. |
| 1874. Mr. Alfred Bell. | 1882. Professor J. Gosselet. <i>Medal.</i> |
| 1874. Professor Ralph Tate. | 1882. Professor T. Rupert Jones. |
| 1875. Mr. W. J. Henwood. <i>Medal.</i> | 1883. Professor H. R. Göppert.
<i>Medal.</i> |
| 1875. Professor H. G. Seeley. | 1883. Mr. John Young. |
| 1876. Mr. A. R. C. Selwyn. <i>Medal.</i> | 1884. Dr. H. Woodward. <i>Medal.</i> |
| 1876. Dr. James Croll. | 1884. Mr. Martin Simpson. |
| 1877. Rev. W. B. Clarke. <i>Medal.</i> | 1885. Professor F. Römer. <i>Medal.</i> |
| 1877. Professor J. F. Blake. | 1885. Mr. H. B. Woodward. |
| 1878. Dr. H. B. Geinitz. <i>Medal.</i> | 1886. Mr. W. Whitaker. <i>Medal.</i> |
| 1878. Professor C. Lapworth. | 1886. Mr. Clement Reid. |
| 1879. Professor F. M' Coy. <i>Medal.</i> | |
| 1879. Mr. J. W. Kirkby. | |
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AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced."

- | | |
|---|--|
| 1876. Professor John Morris.
<i>Medal.</i> | 1881. Mr. G. R. Vine. |
| 1877. Dr. James Hector. <i>Medal.</i> | 1882. Dr. J. Lycett. <i>Medal.</i> |
| 1877. Mr. W. Pengelly. | 1882. Rev. Norman Glass. |
| 1878. Mr. G. Busk. <i>Medal.</i> | 1882. Professor C. Lapworth. |
| 1878. Dr. W. Waagen. | 1883. Dr. W. B. Carpenter. <i>Medal.</i> |
| 1879. Professor Edmond Hébert.
<i>Medal.</i> | 1883. Mr. P. H. Carpenter. |
| 1879. Professor H. A. Nicholson. | 1883. M. E. Rigaux. |
| 1879. Dr. Henry Woodward. | 1884. Dr. Joseph Leidy. <i>Medal.</i> |
| 1880. Mr. John Evans. <i>Medal.</i> | 1884. Professor Charles Lapworth. |
| 1880. Professor F. Quenstedt. | 1885. Professor H. G. Seeley.
<i>Medal.</i> |
| 1881. Sir J. W. Dawson. <i>Medal.</i> | 1885. Mr. A. J. Jukes-Browne. |
| 1881. Dr. Anton Fritsch. | 1886. Mr. W. Pengelly. <i>Medal.</i> |
| | 1886. Mr. D. Mackintosh. |
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AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
 1879. Professor E. D. Cope.
 1881. Dr. C. Barrois.

1883. Dr. Henry Hicks.
 1885. Professor Alphonse Renard.

 AWARDS OF THE PROCEEDS OF THE BARLOW-
 JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

"The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1880. Purchase of microscope.
 1881. Purchase of microscope lamps.
 1882. Baron C. von Ettingshausen.

1884. Dr. James Croll.
 1884. Professor Leo Lesquereux.
 1886. Dr. H. J. Johnston-Lavis.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions for Quarterly Journal ..	4	16	8			
Due for Arrears of Annual Contributions	130	0	0			
Due for Arrears of Admission-fees	79	6	0			
	<hr/>			214	2	8
Estimated Ordinary Income for 1886:—						
Annual Contributions from Resident Fellows, and Non-residents, 1859 to 1861	1480	0	0			
Admission-fees	226	16	0			
Compositions	168	0	0			
Annual Contributions in advance	21	0	0			
Dividends on Consols and Reduced 3 per Cents.	230	0	0			
Sale of Transactions, Library-catalogue, Ormerod's Index, Hochstetter's New Zealand, and List of Fellows	5	0	0			
Sale of Quarterly Journal, including Longman's account	200	0	0			
Sale of Geological Map, including Stanford's account	7	0	0			
	<hr/>			212	0	0

£2551 18 8

THOMAS WILTSHIRE, TREAS.

Feb. 1886.

the Year 1886.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure :						
Taxes and Insurance	36	10	0			
Gas	22	0	0			
Fuel	30	0	0			
Furniture and Repairs.....	15	0	0			
House-repairs and Maintenance.....	15	0	0			
Annual Cleaning	20	0	0			
Washing and Sundries.....	33	0	0			
Tea at Meetings	16	0	0			
					187	10 0
Salaries and Wages :						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	130	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	46	16	0			
Charwoman and Occasional Assistance.....	30	0	0			
Attendants at Meetings	8	0	0			
Accountant	10	10	0			
					880	6 0
Official Expenditure :						
Stationery	25	0	0			
Miscellaneous Printing	22	0	0			
Postages and other Expenses	65	0	0			
					112	0 0
Library					150	0 0
Publications :						
Quarterly Journal	950	0	0			
" " Commission, Postage, and Addressing	90	0	0			
List of Fellows	33	0	0			
Abstracts, including Postage	105	0	0			
					1178	0 0
Balance in favour of the Society					44	2 8
					<u>£2551</u>	<u>18 8</u>

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1885.	73	4	9			
Balance in Clerk's hands, 1 January 1885.	16	2	11			
				89	7	8
Compositions				189	0	0
Arrears of Admission-fees.....	69	6	0			
Admission-fees, 1885	252	0	0			
				321	6	0
Arrears of Annual Contributions				162	12	6
Annual Contributions for 1885, viz.:						
Resident Fellows	1485	15	0			
Non-Resident Fellows ...	15	15	0			
				1501	10	0
Annual Contributions in advance				37	16	0
Dividends on Consols	203	8	5			
,, Reduced 3 per Cents.	30	2	4			
				233	10	9
Taylor & Francis: Advertisements in Journal, Vol. 40..				3	19	3
Publications:						
Sale of Journal, Vols. 1-40	115	2	5			
,, Vol. 41 *	86	14	8			
Sale of Library Catalogue	2	1	0			
Sale of Geological Map	7	5	10			
Sale of Ormerod's Index.....	1	6	8			
Sale of Hochstetter's New Zealand	1	0	0			
Sale of List of Fellows	0	1	0			
				213	11	7
*Due from Messrs. Longman, in addition to the above, on Journal, Vol. 41, &c.....	69	10	6			
Due from Stanford on account of Geological Map	5	14	5			
	75	4	11			

£2752 13 9

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) THOMAS CODRINGTON, }
W. H. HUDLESTON. } *Auditors.*

8 February, 1886.

Year ending 31 December, 1885.

EXPENDITURE.

House Expenditure:	£	s.	d.	£	s.	d.
Taxes	22	10	0			
Fire-insurance	13	13	9			
Gas	21	17	3			
Fuel.....	30	8	6			
Furniture and Repairs	9	17	3			
House-repairs.....	17	1	1			
Annual Cleaning	19	12	0			
Washing and Sundries	32	16	10			
Tea at Meetings.....	16	0	0			
				183	16	8
<hr/>						
Salaries and Wages :						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	130	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	47	14	0			
Charwoman	28	6	0			
Attendants at Meetings.....	8	0	0			
Accountant's Fee	10	10	0			
				879	10	0
<hr/>						
Official Expenditure :						
Stationery	26	11	2			
Miscellaneous Printing.....	22	1	0			
Postages and other Expenses	80	6	2			
				128	18	4
<hr/>						
Library				108	19	9
<hr/>						
Publications :						
Geological Map	12	10	3			
Journal, Vols. 1-40.....	10	13	1			
„ Vol. 41	765	12	0			
„ „ Commission,						
Postage, and Addressing .	87	0	4			
				852	12	4
List of Fellows.....	33	12	6			
Abstracts, including Postage	104	15	0			
				1014	3	2
<hr/>						
Balance in Bankers' hands, 31 Dec. 1885 ..	423	1	6			
Balance in Clerk's hands, 31 Dec. 1885 ..	14	4	4			
				437	5	10
<hr/>						
				£2752	13	9
<hr/>						

“BIGSBY FUND.” TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance at Bankers', 1 January, 1885	12	5	7	Medal awarded to M. Alphonse Rénard	12	5	7
Dividends on the Fund invested in New 3 per Cents	6	1	8	Balance at Bankers', 31 December, 1885	6	1	8
	<u>£18</u>	<u>7</u>	<u>3</u>		<u>£18</u>	<u>7</u>	<u>3</u>

VALUATION OF THE SOCIETY'S PROPERTY; 31 December, 1885.

PROPERTY.	£	s.	d.	DEBITS.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. xi. &c.	69	10	6	Balance in favour of the Society	8762	6	2
Due from Stanford on account of Map	5	14	5				
Due from Subscribers to Journal	4	16	8				
Balance in Bankers' hands, 31 Dec. 1885	423	1	6				
Balance in Clerk's hands, 31 Dec. 1885	14	4	4				
Funded Property:—	£	s.	d.				
Consols, at 100	6999	7	4				
Reduced 3 per Cents, at 100	1036	5	5				
Arrears of Admission-fees (considered good)	130	0	0				
Arrears of Annual Contributions (considered good)	79	6	0				
	<u>£8762</u>	<u>6</u>	<u>2</u>		<u>£8762</u>	<u>6</u>	<u>2</u>

[N.B. The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.]

THOMAS WILTSHIRE, Treas.

10 Feb. 1886.

AWARD OF THE WOLLASTON MEDAL.

In handing the Wollaston Gold Medal to Mr. WARINGTON W. SMYTH, F.R.S., for transmission to Prof. A. L. O. DES CLOIZEAUX, the President addressed him as follows :—

Mr. WARINGTON SMYTH,—

In the absence, which we much regret, of Prof. Des Cloizeaux, I must request you to transmit to him this Medal.

Geology is the child of two parents,—mineralogy and biology. If we look to the latter to bid the dry bones and buried relics of organisms once more live, we appeal to the former to disclose the nature and constitution of the earth's framework whereon they flourished. It is therefore only just that our Society should seek opportunities of acknowledging the aid which we receive from mineralogists ; and it would be difficult to find one on whom this Wollaston Medal could be more fitly conferred than on Prof. Des Cloizeaux. To enumerate the papers which he has written would be a formidable task ; they numbered 141, so long as fourteen years ago ; what, then, must be the present total ? I may, however, point, in passing, to his admirable 'Manuel de Minéralogie,' and allude, as more directly bearing on the work of this Society, to his papers on the classification of hyperites and euphotides, on the geysers of Iceland, on the action of heat upon the position of the optic axes in a mineral, and the numerous memoirs on the distinction of minerals by their optical properties, especially those relating to microcline, and to other species of felspar, of the importance of which students of microscopic petrology are daily more sensible. I esteem it a great honour to be the means of carrying into effect the award of the Council by placing in your hands, to be transmitted to Prof. Des Cloizeaux, the Wollaston Medal, founded "to promote researches concerning the mineral structure of the earth."

Mr. WARINGTON W. SMYTH, in reply, said :—

Mr. PRESIDENT,—

It is, Sir, with more than ordinary satisfaction that I am privileged to receive for, and to transmit to, Prof. Des Cloizeaux the Medal founded by Dr. Wollaston. No one can fail to appreciate the appropriateness of this award when we consider the researches into the physical characters of minerals which have contributed so much to the petrological branch of our science, in which you, Sir, have taken so prominent a part. But 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. The Society will regret to learn that Prof. Des Cloizeaux has been prevented by domestic anxieties from being present to-day.

AWARD OF THE WOLLASTON DONATION FUND.

The PRESIDENT then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. J. STARKIE GARDNER, F.G.S., and addressed him as follows :—

MR. STARKIE GARDNER,—

The small number of students and the paucity of memoirs seems to indicate that fossil botany is one of those subjects of which the difficulties repel rather than fascinate the neophyte. If perhaps these are in some respects less formidable in the plant-remains of the earlier Tertiary period, if, in studying them, recent throws some light on fossil botany, yet the practical difficulties of obtaining, developing, and preserving specimens are so great that no little ardour and patience are demanded from one who devotes himself to the subject. For years this has been your special work : after thoroughly exploring the flora of the Eocene Tertiaries on the coast of Hampshire and in the Isle of Wight, you are now, and have for some time been, engaged in communicating to us the fruits of your labours through the medium of the Palæontographical Society, thereby earning the thanks of students. Your researches also of late years have been extended to Antrim, Mull, and even Iceland, and their results cannot fail to be of the highest interest in regard to the age of these floras, and their relation to those which occur in the Hampshire district. In recognition of past and in aid of future work, the Council have awarded to you the balance of the Wollaston Fund, which I have much pleasure in handing to you.

MR. GARDNER, in reply, said :—

MR. PRESIDENT,—

I beg to return my thanks for the honour the Council have done me in placing the balance of this fund at my disposal. The amount of leisure I am able to command has not permitted me to contribute towards the advancement of geology in this country in anything like the same proportion as my professional brethren ; but I think I may fairly claim to yield to none in my devotion to its pursuit. The subject I somewhat unfortunately monopolize is one of such magnitude that, at the best, very many years of such work as I am able to devote to it must elapse before even a first general impression of the composition of our Eocene floras can be published. I am, however, so deeply impressed with the importance of the study that I am prepared to sacrifice much in order that the time required may not be unduly prolonged. I am convinced that, in addition to the ordinary botanical, palæontological, and evolutionary interest attaching to it, it will be found to present the solution of many problems as to the former relative positions of land and sea and the climatic changes

accompanying their successive redistribution. I need hardly add that I regard the award made me this day as a direct encouragement to persevere in the line of research I have chosen.

AWARD OF THE MURCHISON MEDAL.

The PRESIDENT next presented the Murchison Medal to Mr. WILLIAM WHITAKER, B.A., F.G.S., and addressed him as follows:—

Mr. WILLIAM WHITAKER,—

To many members of the Geological Survey of Great Britain since the date of its constitution we are indebted for work freely done—beyond the sphere of their more strictly professional duties. Its chiefs, from the days of Sir H. De la Beche to the present distinguished Director-General, Dr. A. Geikie, have been among the most valued contributors to our Journal, and have enriched geological literature by their longer writings; while among its other members, few have done more than yourself in following the example of its leaders. On the present occasion I will only allude to the various Memoirs of the Geological Survey, especially that on the London Basin, in which you have taken so large and important a share, and will dwell rather on your contributions to our own Journal and to other publications. Your papers on the western end of the London Basin, and on the Lower London Tertiaries of Kent, deserve to be ranked with the classic memoirs of Prestwich as elucidating the geology of what I may call the Home District; and your last contribution to its deep-seated geology is still too fresh in our memories to need more than a mention. We do not forget your varied and valuable contributions to the Geological Magazine, especially those on the Red Chalk of Norfolk, on the Water-supply from the Chalk, on the formation of the Chesil Bank (written jointly with Mr. Bristow), a paper, as it seems to me, of remarkable suggestiveness, and last, but by no means least, “On Subaerial Denudation,” in which, as remarked by the late Mr. Charles Darwin, you had “the good fortune to bring conviction to the minds” of your fellow-workers by means of “a single memoir.”

We are also greatly indebted to you for your labours in reference to the history of the literature of geology, a task involving not a little labour, which, though of the greatest value to students, is to all unremunerative and would be, to many, exceptionally toilsome. Of this, your care for several years of the Geological Record, and the lists of books and memoirs relating to the geology of various counties in England, are conspicuous instances.

There is a peculiar appropriateness in the award to you of this Medal, founded by Sir Roderick Murchison, one of the illustrious chiefs of your Survey, and I have the greatest pleasure, on behalf of

the Council of the Geological Society, in placing it in your hands together with the customary grant from the Fund.

Mr. WHITAKER, in reply, said :—

Mr. PRESIDENT,—

To the labourer in the fields of science the best reward is to find that his work is approved by his fellow-workers. In the course of my geologic life the pleasure of such approval has been given me at various times and in various ways ; and these acknowledgments are now crowned by the award of the Murchison Medal.

Knowing how carefully such awards are made by the Council, and knowing, too, how many good and true men there are from whom to choose, I cannot but take this Medal as a reward of the highest value, which, whilst showing that my work in the past has been thought not ill done, will cheer me on to fresh work in the future.

I am glad, Sir, to hear the remarks which you have made as to the connection of the Officers of the Geological Survey with this Society ; for it has always been a satisfaction to me to see papers from Survey men, past and present, in the Society's Journal.

The pleasure I now feel is enhanced by receiving this Medal from the hands of an old friend, whose friendship, begun many years ago, has continued with no break in succession, without disturbance, and in perfect conformity.

To conclude, my thanks are due, not only to the Council for this award, but also to you, Sir, for the kind and flattering words with which you have accompanied it, as well as to my friends and brother-hammerers for the way in which they have shown their pleasure at the great honour now done to me.

AWARD OF THE MURCHISON GEOLOGICAL FUND.

In presenting the Balance of the Proceeds of the Murchison Geological Fund to Mr. CLEMENT REID, F.G.S., the PRESIDENT said :—

Mr. CLEMENT REID,—

The later Pliocene and the Pleistocene deposits of East Anglia offer to geologists a series of problems as difficult as they are attractive. We are indebted to you for much valuable information on the exact distribution and the fossil contents of these varied deposits, which owing to peculiar local circumstances often present exceptional difficulties, and demand exceptionally patient study on the part of the investigators. Your memoir on the Forest Bed of Norfolk is a contribution of especial value to students as affording them fuller and more precise information than could previously be obtained, while the pages of our Journal and of the Geological

Magazine testify to the zeal and thoroughness with which you have applied yourself to these and kindred questions. In conferring upon you this award from the Murchison Fund, which I have great pleasure in placing in your hands, the Council of the Geological Society hopes that it may aid you in prosecuting your studies in this department of geology and extending them to localities which could not be visited by you in the discharge of your professional duties as a Member of the Geological Survey of Great Britain.

Mr. CLEMENT REID, in reply, said :—

Mr. PRESIDENT,—

I have sometimes felt discouraged at the small results of my work. But this welcome and unexpected award by the Council of the Geological Society is a recognition that the work is not considered altogether worthless, and will encourage me still to persevere. Though a large portion of my observations have been made in the course of the Geological Survey, I have also devoted my leisure time to the study of various questions in Pleistocene and Pliocene natural history. This award of the Murchison Fund will now enable me to undertake a more thorough examination of many of the less-known deposits.

AWARD OF THE LYELL MEDAL.

The PRESIDENT next presented the Lyell Medal to Mr. WILLIAM PENGELLY, F.R.S., F.G.S., and addressed him as follows :—

Mr. PENGELLY,—

The Council of the Geological Society has awarded you the Lyell Medal and a sum of twenty guineas from the Fund in recognition of your lifelong labours in the cause of geology, and more especially of your investigations in those caverns of the south-west of England by means of which our knowledge of the condition of Britain during the latest epoch of geological history has been so largely augmented. To exhume the contents of a cavern, not only the lair of wild beasts, but also an abode of men in those ages when, to quote the words of the old Greek tragedian,

“Like tiny ants they dwelt in sunless caves,” *

requires the exercise of unwearied patience and, in addition, of extensive knowledge and critical acumen. By the labours of the Committee, of which you were the hands and the eyes, and at least a fair proportion of the compound brain, Mr. MacEney's long-neglected discovery in Kent's Hole was placed beyond all dispute, and the contents of that cavern, its succession of deposits, its relics

* Æschylus, Prom. Vinct. 461.

of extinct animals, and its tools of stone and bone, denoting more than one stage of civilization, have been made known to the world.

In like way the virgin ground of the Brixham cave was investigated, and its valuable contents have been rendered accessible to students. All this you have done, not as the fruit of secured leisure, but in the intervals of a busy life, of which, in the full sense of the words, time was money; and you began this work at a period when, owing to mistaken prejudices, you incurred no small risk of obloquy and personal loss. Your work at Bovey Tracey and your papers on the later geology of Devonshire and Cornwall are too well known to need more than a passing allusion; the Torquay Museum and the Transactions of the local societies will be a lasting monument of your zeal in stimulating scientific researches in the neighbourhood of your home. There is a peculiar fitness in the award to you of this Medal, a memorial of the fearless and illustrious author of the 'Principles of Geology' and of the 'Antiquity of Man.'

I esteem myself exceptionally fortunate in being commissioned to place it in your hands, and being thus enabled to testify my regard for so valued and genial a friend.

Mr. PENGELLY, in reply, said that he could not conceal from himself, and did not wish to conceal from the Fellows, the gratification that he felt at receiving this award. He had studied Geology for some fifty years, although he had appeared but little in the rooms of the Geological Society, his publications on geological subjects having been chiefly contributed to those local Societies in whose neighbourhood his researches had been carried on. His gratification at this award compensated for much obloquy, especially as it bore the name of an old and loved friend with whom he had worked much and often. No doubt the founder of the Medal intended that its award should serve not only as a reward for work done, but as a stimulant to further exertion. It came to him so late in the day, however, that he could hardly hope to do very much more; but although he himself might not be urged by it to renewed efforts, the stimulus might act vicariously, as the knowledge that he had received this recognition of such services as he had rendered to science would doubtless get spread abroad in Devonshire, and would probably serve as an incitement to many local workers to persevere in their studies.

AWARD OF THE LYELL GEOLOGICAL FUND.

In handing the balance of the Proceeds of the Lyell Geological Fund to Dr. HENRY WOODWARD, F.R.S., F.G.S., for transmission to Mr. D. MACKINTOSH, F.G.S., the PRESIDENT addressed him as follows:—

Dr. WOODWARD,—

I have much pleasure in placing in your hands, as representing Mr. Mackintosh, the balance of the Lyell Donation Fund awarded to him by the Council of the Geological Society. In him we have a second instance of the way in which, through an untiring zeal for science, the rare intervals of a hard-worked life may bear fruit so largely augmenting the common stock of geological knowledge. There are few problems more interesting than that of the physical condition of our native land during the period commonly designated the Glacial Epoch; but for its solution an exact knowledge of the distribution of erratics and an identification of their points of departure is absolutely necessary. Those who, like myself, have attempted to adjust the rival claims of glacier and floe, of the ice-chariot *versus* the ice-ship, as vehicles of boulder-transport, can hardly speak too highly of the value of the papers on British erratics which he has contributed to our Journal and to other publications. I trust that this award may not only be gratifying to him as a mark of our appreciation, but also help him in continuing his labours in a field where, notwithstanding them, much still remains to be done.

Dr. WOODWARD, in reply, said :—

Mr. PRESIDENT,—

The intelligence of the decision of the Council has had a most cheering effect on Mr. Mackintosh, and will brighten the remaining years he may have left to him. It is well known to Fellows of this Society what has been the nature of Mr. Mackintosh's work, and what good and careful observations he has made, extending over long years of wandering up and down through England and Wales, and carefully observing wherever he went. I cannot do better than read the following letter from Mr. Mackintosh, which, indeed, is addressed to yourself. He says :—“ In thanking you for the honour conferred upon me by the Award of the Lyell Donation Fund, I may mention the fact that 25 years ago I was elected a Fellow of this Society, and that Sir Charles Lyell was one of those who signed my certificate. I am now seventy years of age; this is the second occasion that my work has been so much honoured, for I am proud to be able to state that I was presented with the Kingsley Medal of the Chester Society of Natural Science in 1881.”

AWARD OF THE BARLOW-JAMESON FUND.

The PRESIDENT then handed the Award from the Barlow-Jameson Fund to Dr. W. T. BLANFORD, F.R.S., for transmission to Dr. H. J. JOHNSTON-LAVIS, F.G.S., and addressed him as follows :—

Dr. BLANFORD,—

I will ask you to transmit this Award to Mr. Johnston-Lavis. In this country happily the volcanic fires have long ceased to glow, and the earthquake seldom causes more than a transient tremor. It is otherwise on the shores of the Bay of Naples, where again and again during the last eighteen centuries Vesuvius has rained down ruin; and of late years the earthquakes of Ischia have wrought destruction on the works, and desolation in the homes, of men. It is true that these phenomena of the darker side of nature have not been unobserved by the many illustrious men of science to whom Italy has given birth; but “the curse of Babel” has debarred some of us from access to their works. This alone gives an exceptional value to the elaborate studies which Mr. Johnston-Lavis has undertaken of the various eruptive-products of Vesuvius, and of the Ischian earthquakes. There is yet another advantage, that natural phenomena should be studied by men of different nations, diverse training, and varied habits of mind. In recognition of his past labours and in furtherance of future work in the vicinity of Naples, the Council have awarded to him a grant from the Barlow-Jameson Fund, which I have much pleasure in placing in your hands.

Dr. BLANFORD, in reply, said that the best mode of replying to the kind remarks made by the President would be to read a letter which he had received from Dr. Johnston-Lavis. That gentleman said:—

“It was with a considerable amount of astonishment and pleasure that I received your letter announcing the Grant from the Barlow-Jameson Fund, since the news was so perfectly unexpected. The honour thus paid me for my attempts to clear up some questions in vulcanology and seismology will stimulate me to further follow that line of investigation, with the hope of adding something more to our knowledge of those subjects.

“My professional work at this season prevents me from having the great pleasure of being present in person to receive this mark of esteem from the hands of our President. Will you kindly express my deep gratitude to the Society for so generously conferring such an honour upon me.”

THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

PROF. T. G. BONNEY, D.Sc., LL.D., F.R.S.

GENTLEMEN,

During the past year our losses by death, I deeply regret to say, have been hardly less numerous and no less severe than they had been when last I had the honour of addressing you.

On April 15th another link which connected the present with the "heroic age" of Geology, was broken by the death of the EARL of SELKIRK, who expired after a short illness, at the family seat of St. Mary's Isle, Kirkcudbrightshire, in the seventh-sixth year of his age. His father, the seventh Earl, will be long remembered in Canada as the founder of settlements of Highlanders in Prince Edward's Island and in that district of the present province of Manitoba which still bears his name. The troubles which, in its early days, beset the latter colony,—troubles, which might almost be called persecutions, had not their motive been zeal for mammon—required the founder's presence in Canada, and he sailed thither in 1815, taking with him his family, including the late Earl, Dunbar James Douglas, then a child six years old. The boy returned to England in 1819, and after the death of his father in the following year, went to Eton and in due course to Christ Church, Oxford, where he had a distinguished career, obtaining a first class in mathematics. Henceforward a large part of the Earl of Selkirk's time was devoted to those duties which fall naturally to the share of one born to a considerable estate and hereditary honours, and his conscientious discharge of them won for him the respect and love of all classes in Kirkcudbrightshire. He took a deep interest in the affairs of the Church of Scotland, and, in addition to his private duties, filled the responsible positions of Lieutenant of the Stewartry, of a representative peer of Scotland, and of Keeper of the Great Seal of that ancient kingdom. But his life, even if it may be called uneventful, was far from monotonous. He travelled much in days when locomotion was less easy than at present. There were few countries in Europe of which he had not some personal knowledge. He had visited Egypt, Palestine, and Syria, had stood in the trenches at Sebastopol, and in his yacht had cruised about the Mediterranean; while still a young man, he crossed the Atlantic a second time for an extended tour in Canada and the United States, and in 1871 he went to India. A keen observer and lover of science, these travels were to Lord Selkirk no desultory wanderings, but he returned from them with augmented knowledge stored up in a remarkably retentive memory. This, added to his natural ability and wide experience, would have enabled him to attain a high place, had he desired it, among students of science; but though

a lover of books, and intimate with all the leading men of science of his generation, he does not appear to have written much, and he only contributed two papers to our publications; probably he found that the duties of his position interfered with the continuous study which science demands; few men, however, can have loved Nature more than he, and his body and mind happily remained vigorous until the end. He was with us, then in his seventy-sixth year, a very few weeks before his death, looking so hale and well that one would have predicted an extension of his term of life to at least fourscore years, deafness appearing to be the only infirmity from which he suffered. Unhappily a chill, caught while driving in one of the bitter winds of last spring, terminated in an inflammatory attack which proved speedily fatal. He became a Fellow of the Society in 1830, and of the Royal Society in 1831. He married, late in life, a daughter of Sir Philip Grey-Egerton, formerly so well known to this Society, and as he died without issue, the earldom is merged with the titles of the House of Hamilton. In private life few men have been more deservedly beloved than Lord Selkirk. In the home circle, among his tenantry, in the larger duties of life, he was distinguished no less for his rectitude of principle than for his amiability of character. To our Society the loss is great. True, he did not contribute much to our Journal, and of late years was prevented by his deafness from joining in the debates, but he was one of those men who seemed to exercise a softening and refining influence wherever he went. The present age, with its hurry, its competition, its occasional asperities, which ruffle sometimes even the calm of science, can ill spare one in whom courtesy and kindness seemed innate, who had all the grace of the "old school," without its occasional affectation of condescension, who, in short, was entitled to bear, in the fullest and highest sense of the word, "the grand old name of gentleman."

On October 14th last, after an illness of some duration, passed away at his Brighton residence, THOMAS DAVIDSON, of Moir House, Midlothian. Born in 1817, his early days were chiefly spent on the Continent. At first art divided his regards with science, and in Paris he studied the one in the studios of Horace Vernet and Paul Delaroche, the other in the lecture-rooms of Elie de Beaumont, Milne-Edwards, Geoffroy St.-Hilaire, and other Professors of the Sorbonne. At Edinburgh, where he matriculated, he came under the influence of Jamieson; then, after a further study of art in Rome, he made it subservient to science, and at the instance of Leopold von Buch, undertook the examination of the Brachiopoda. The first fruits of his labour in this class, at that time but imperfectly understood, appeared together with some contributions from the late Dr. Carpenter and others in the volume of the Palæontographical Society for 1851. Part followed part with little break in the annual succession of volumes, such was the industry of the author, who, having succeeded to considerable property, was enabled to devote his whole time to science. At last, in the volume for 1870, the magnificent mono-

graph on the British Brachiopoda, occupying three quarto volumes, with very numerous plates, all drawn by the author's own hand, was completed. Many men would now have been content to rest from their labours, and to repose upon their well-earned reputation. Not so with Davidson. As he had passed onwards from formation to formation, new material, through the zeal of collectors, had continued to accumulate in the fields which he had left, and the researches of Mr. Maw and others in the Wenlock Shales, had provided fresh opportunities of ascertaining the internal structure of the earlier Brachiopoda. So a supplementary memoir was begun, the first part appearing in the volume of the Palæontographical Society for 1873, the last in that for 1885, the whole forming three volumes, similar in form to the original work. But the volumes of the Palæontographical Society were not the only outlet for the results of Dr. Davidson's industry. Frequent contributions, commonly relating to the Brachiopoda, but sometimes to more general questions, often beautifully illustrated by the author's own hand, appeared in our Journal, the Geological Magazine, the Transactions of the Linnean Society, and the Annals and Magazine of Natural History, not to mention other publications, British and foreign. His latest work, unpublished, but happily completed at his death, was a Memoir on Recent Brachiopoda, which will appear in the Linnean Transactions. Mr. Davidson was elected a Fellow of this Society in 1852, and was for two years one of its Honorary Secretaries, receiving in 1865 the Wollaston Medal; in 1857 he was elected a Fellow of the Royal Society, and in 1870 was awarded one of the Royal Medals. He was also a Fellow of the Linnean Society, and an honorary member of numerous Societies, British and foreign. In 1882 the University of St. Andrews conferred upon him the honorary degree of LL.D.

By the town of Brighton, where of late years he chiefly resided, he will long be remembered for his exertions on behalf of science and his gifts to the Museum. With that large-minded liberality which distinguished him throughout life, he has bequeathed to the National Museum at South Kensington his magnificent collection of Brachiopoda, together with his books illustrative of the study.

His health had been failing for some time before his death, but he was able to continue his scientific labours almost to the last. In him we have lost one of those accomplished specialists who, though they have selected a limited field for their labours, have dealt with it in so philosophic a spirit that they have aided largely in the progress of science. It will be so long before the work of Thomas Davidson is forgotten by geologists and biologists that he might have ventured to apply to the volumes which were the chief work of his life the well-known Horatian verse

“Exegi monumentum ære perennius.”

On November 10th, 1885, a lamentable accident deprived our Society of one of its most eminent members, Dr. WILLIAM BENJAMIN CARPENTER. Born at Exeter in the year 1813, he was educated at

a school kept by his father, a Unitarian Minister in that town. His early bent was to engineering, but ultimately he was attracted into the medical profession, receiving his education for that purpose at University College, London, and at the University of Edinburgh, where he graduated as M.D. in 1839. For a time Dr. Carpenter practised medicine in Bristol, but in the year 1844, encouraged by the success which had attended his first important work, 'The Principles of General and Comparative Physiology,' he decided to devote himself to a literary and scientific career, and removed to London, where he was appointed Fullerian Professor of Physiology at the Royal Institution, and to a Professorship at University College. In 1851 he was appointed Principal of University Hall, which office he held till 1859. He resigned these Professorships three years before this date on his election to the Registrarship of the University of London. In this office his varied culture, great powers of organization, calm judgment, and courtesy of manner were of the highest service to the University, and he occupied this post until the year 1879, when he retired on a well-earned pension.

Though a very large part of Dr. Carpenter's busy life was devoted to the study of Physiology, and thus lies outside the scope of our Society, he was deeply interested in the problems of Geology, and has laid its students under lasting obligations. His investigation of the microscopic structure of the shells of the Mollusca, his researches on Echinodermata, his studies of the Foraminifera, above all the magnificent volume describing and figuring the exquisite structures of these lowly organisms, published, with the aid of Professor Rupert Jones and Mr. W. K. Parker, among the serial volumes of the Ray Society, have been of inestimable value to geologists. In him we may recognize one of those pioneers and masters in microscopical work, who have indicated how important in the world of nature is the "task of the least." Dr. Carpenter's name will also long be associated with the difficult yet fascinating controversy concerning *Eozoon canadense*, which abnormal structure he was among the earliest to claim as an organism and as belonging to the Foraminifera. At the time of his death he was engaged upon an exhaustive memoir, in which the results of his later researches were to be embodied, but this unhappily has been left in a very incomplete state. Of the question itself, whether Eozoon be truly an organism or only a most singular mineral simulation, we may truly say, *adhuc sub judice lis est*; but whichever way it be decided, it will hardly diminish the value of Dr. Carpenter's researches; for even if this supposed glimpse of the dawn of life prove to be an illusion, yet in the quest much will have been learnt, and the investigator will not have returned empty-handed.

But Dr. Carpenter has another claim on the gratitude of geologists. It was very largely owing to his perseverance and activity that those deep-sea researches were undertaken which at last culminated in the 'Challenger' expedition. In the earlier of these Dr. Carpenter took part, spending in this way no inconsiderable portions of his

vacations. Twenty years since, the depths and principal contours of the great ocean-basins were almost unknown, their abysses were deemed lifeless, their currents and temperatures were very inadequately determined. On all these points a flood of light has been thrown, so that many as are the mysteries yet unsolved, the foundations are now laid firm and sure on which the labourers of the future may build.

Dr. Carpenter was elected a Fellow of our Society in 1847, and received the Lyell Medal in 1883; he was elected into the Royal Society in 1844, and was awarded a Royal Medal in 1861. He was made a C.B. in 1879, received in 1871 the honorary degree of LL.D. from the University of Edinburgh, and was President of the British Association at the Brighton meeting in 1872. In the following year he was elected a Corresponding Member of the Institute of France.

Dr. Carpenter belonged to a family more than one member of which has made some mark in the world. His brother, the late Dr. P. P. Carpenter, was eminent for his knowledge of conchology; and the philanthropic labours of his sister Miss Mary Carpenter will long be held in grateful remembrance. More than one of his sons has imitated his father's devotion to science, one of whom, Dr. P. H. Carpenter, has contributed to our Proceedings some very valuable papers on the Echinodermata.

The general character of Dr. Carpenter's mind has been so well described in a feeling and appreciative notice, that I shall venture to quote from it a few sentences:—"He was a natural philosopher in the widest sense of the term, one who was equally familiar with the fundamental doctrines of physics, and with the phenomena of the concrete sciences astronomy, geology, and biology. It was his aim, by the use of the widest range of knowledge of the facts of Nature, to arrive at a general conception of these phenomena as the outcome of uniform and all-pervading laws"*. To these I may add some other characteristics which, during a friendly intercourse of full fifteen years, specially impressed themselves on my own mind. One was the comprehensiveness, I might almost say the versatility, of his mind. His interests were exceptionally wide, his knowledge surprisingly multifarious; yet the latter was always accurate and thorough. Dr. Carpenter was no narrow scientist, but a man of an unusually large general culture; for whom music, arts, poetry, philosophy, all had their charms. His accurate memory, his rich and varied stores of knowledge gave an especial value to his lectures and conversation, though perhaps they sometimes produced an exuberance in the treatment of a subject, and caused him to forget that the interest of his listeners was less unflagging than his own; yet this excess, if such it were, was only the natural outcome of Dr. Carpenter's conscientious thoroughness and absorption in his work, which caused him to forget both himself and his hearers, and resulted from his high sense of duty, which forbade him to deal superficially with any subject, even the most ordinary. Duty, indeed, as the writer I have already quoted observes, "was the most dominant

* Prof. E. Ray Lankester in 'Nature,' Nov. 26, 1885.

conception of his life ;” but this conception, while it strengthened and ennobled himself, did not produce censoriousness or austerity towards others ; for nowhere was he more attractive than in the social, or beloved than in the domestic circle. He seemed to me—and I have especial reason to know it—to be above petty jealousies and resentments. To younger men he was always helpful and generous, and extended to many some share of that affectionate sympathy which made him so beloved in his own family. The evening of Dr. Carpenter’s days was peaceful, and he seemed to have only just begun to feel the increasing burden of years when through a short and painful passage he entered into his rest, and, as we may humbly hope, into a fuller knowledge of that Truth of which he had been through this life so earnest a seeker.

D. C. DAVIES died suddenly on Sept. 19th last, while returning from Norway to England, on board the steamship ‘Angelo.’ He was born at Oswestry, and being left an orphan at an early age, was entirely self-educated. Apprenticed to an ironmonger in his native place, he did not cease to be a zealous student, and before long gave evidence of a special bent towards geology. This, especially the economic side, gradually absorbed more of his attention. What had been begun as a pastime became a source of income, and about twelve years since, he was enabled to give up trade, and engage in the business of a mining engineer, in which capacity he made many journeys and, as I am informed, met with considerable success. He contributed three papers to our Journal, all bearing upon the geology of North Wales or its border-land ; but he also published separate works on ‘Slates and Slate-Quarrying,’ on ‘Metaliferous Mines,’ and on ‘Earthy and other Minerals.’ He also wrote largely in periodical literature both on scientific and on miscellaneous subjects. He was moreover a lay preacher, and had published a volume of sermons. His death, from heart-disease, was very unexpected, for he was still in full work and had only reached the age of fifty-eight.

JAMES FERGUSSON was born at Ayr in the year 1808, and received a part of his education at the High School of Edinburgh. He entered a merchant’s house, and proceeding to India became a partner in an important business. On retiring from this, he travelled through various parts of the East, chiefly with a view of studying their architecture, after which he returned to England, where he spent most of the remainder of his life. It is on his works on architecture that his reputation will chiefly rest. If his views, as on the age of the Kubbet-es-Sakharah at Jerusalem, and on dolmens and other megalithic monuments were occasionally somewhat paradoxical, these are forgotten in the merits of his ‘Histories of Architecture,’ and of his great works on the religions and architecture of India, to mention no other volumes or memoirs. It must not, however, be forgotten that he published a paper in our Proceedings on “Recent Changes in the Delta of the Ganges,” which has

been often and deservedly quoted. He became a Fellow of this Society in 1864, having been elected into the Royal Society the previous year, and he received the degree of LL.D. from the University of Edinburgh in 1882. He died on January 9th, to the great regret of a numerous circle of friends.

The death of Professor JOHN MORRIS, in the opening days of the present year, severed one of the few remaining links between the past and the present generation of geologists. Born on February 19th, 1810, at Homerton, he received his education at private schools and was afterwards engaged in business as a pharmaceutical chemist at Kensington. His inclination to science was soon manifested, and at the outset he took great interest in astronomy, one of his earliest papers, published in the 'Magazine of Natural History' for 1836, being some observations on the Aurora Borealis. Before this date, however, he had become interested in geology, and had begun to collect materials for a catalogue of British fossils. While thus engaged he published a valuable series of preliminary notes in the 'Magazine of Natural History,' commencing in the year 1839, and the first complete edition of the work appeared in 1845. A second edition was published in 1854, and the last years of his life were occupied by the preparation of a third edition, for the publication of which he was endeavouring to arrange at the time of his death. This catalogue, to quote the words of an appreciative memoir of Professor Morris, published in the 'Geological Magazine' for 1878, "may be placed among the most important contributions to modern Geology. It is far from being a mere compilation, as every one who has worked with it can testify. Every group, every genus, every species was made the subject of exact study, and in each department the specialist is surprised to find the advanced views of this great master in palæontology. The work, with its wonderful accuracy in detail, has contributed largely to the elaboration of stratigraphical geology by supplying the life-data so necessary for such a task."

In 1853 and 1854 Morris accompanied the late Sir Roderick Murchison on geological tours in Europe, and in the year 1855 he was appointed to the chair of Geology in University College, which he held until 1877, finally retiring from business some little time after his election. Inadequate as was the remuneration of this post, Professor Morris devoted himself most energetically to the discharge of its duties, delivering full courses of lectures, accompanying his pupils on geological excursions, and enriching the collection with numerous specimens, the fruits of his rambles. Of the value of the gifts which he made to us at University College I can speak from the fullest personal knowledge, and may add that after my appointment as his successor, he not only presented numerous specimens and appliances for teaching, but was in the habit of frequently visiting the College to help me in arranging and identifying specimens. In recognition of his services, the Council of

University College, on his retirement from the chair of Geology, appointed him Emeritus Professor.

He became a Fellow of this Society in 1845, has more than once served on the Council, and has been one of the Vice-Presidents. I may add that, within my own memory, his own consent alone was wanting to secure his nomination to the Society as President. In recognition and in aid of his scientific labours, he was awarded the balance of the Wollaston Donation Fund in the years 1842, 1843, 1850, and 1852, and the Lyell Medal (its first award) in 1876. He took a keen interest in the Geologists' Association, as in every movement which aided in furthering an interest in geology, and was its President from 1868 to 1870, and again in 1877 and 1878. It is pleasant to record that though one of those men of whom we may truly say that in science "he did good by stealth and blushed to find it fame," his services were not unappreciated, both in this and other countries. In the year 1870, a valuable testimonial was presented to him by numerous friends and admirers, and eight years later a second, chiefly subscribed by members of the Geologists' Association. He was elected an honorary member of many scientific societies, British and foreign, and in 1878 was admitted to the Freedom and Livery of the Turners' Company of the City of London. A few months later the University of Cambridge, in recognition of his scientific eminence and of the services which he had rendered in editing the Catalogue of Cambrian and Silurian fossils drawn up by the late Mr. Salter, and on other occasions, conferred upon him the honorary degree of Master of Arts. This recognition on the part of a University to which he was especially attracted by ties of private friendship with several of its members, with which also he had been officially connected by acting as deputy for the late Professor Sedgwick and as one of its examiners, gave Professor Morris the liveliest pleasure, and he indicated his appreciation by placing his name on the boards of St. John's College, selecting that for reasons which may readily be conjectured.

Professor Morris was a born teacher; to a memory of extraordinary retentiveness he united a remarkable power of lucid exposition. He was able, even at the shortest notice, to express his ideas simply but clearly, clothing a train of well-connected reasoning in language often chosen with unusual felicity. Such was his modesty, that it was at times almost necessary to thrust him forward to speak, yet after a few sentences all nervousness seemed to disappear; the enthusiasm of the speaker began to animate his audience, keeping them enthralled as he poured out the rich stores of his knowledge. His friends were wont to say—and I venture to assert that it is no exaggeration—that he was a walking encyclopedia of geology. This, indeed, I know, that I have never asked him a question—and these were many and various—without obtaining in reply some valuable information.

The accuracy and retentiveness of his memory were something extraordinary; not only the names, but the whole history of the specimens which he had collected, and the details of sections which

he had examined years before, were readily retalled without reference to note-books; indeed I doubt whether he kept diaries or made any but the briefest memoranda. Moreover, the many-sidedness of his knowledge was exceptional; not only was he, as universally admitted, eminent in all branches of palæontology and stratigraphy, but also he was no mean proficient in mineralogy and petrology. Yet he was no mere gatherer of learning. His critical, or perhaps I should rather say, his judicial powers were not less remarkable. He saw almost by instinct the weak point of a theory; and a "brilliant hypothesis," in its brief day of fashion, found small favour with him. Yet more, while delighting most in the scientific aspect of geology, he was so intimately acquainted with its practical applications that he might have added largely to his income by acting as a consulting geologist. This, however, he could rarely be induced to do; while anxious to make sufficient provision for old age, and with this end living always with the utmost frugality, he refused many opportunities of augmenting his income and thus of doing with ease that which he accomplished with difficulty.

Professor Morris's written contributions to science are numerous, but they are less numerous than his friends desired. In this matter also his shrinking from self-assertion was evident. A paper had to be almost extorted from him by friendly persistence, and I have known him press the information at his command on another rather than put pen to paper himself. Still the biography in the Geological Magazine, to which I have already referred, records a very considerable list of papers, in addition to his 'Catalogue of Fossils' and the volume on the Great Oolite Mollusca, written jointly with the late Dr. Lycett, as one of the memoirs of the Palæontographical Society. Since this date (1878), a few, but only a few, have been added. These papers, however, will serve to indicate the remarkably wide range of Professor Morris's knowledge. They embrace subjects mineralogical, stratigraphical, and palæontological, and while among the last named, hardly any important class in the animal kingdom is unnoticed, there are several devoted to fossil botany, of which rarely studied branch of science Professor Morris had an exceptional knowledge. He was, I believe, the first to detect the presence of Lycopodiaceous spores in Coal. But if he abstained more than his friends desired from placing his views on record by means of the printing-press, he was liberal in imparting knowledge in all other ways. For years he was assiduous as a geological lecturer, not only, as I have said, in University College, but in more temporary appointments at many other places. His hand was present to help in the books of more than one of his illustrious contemporaries, and he was so liberal in communicating information to his friends that one of them has said that "it was often difficult for him to distinguish what was his own work and what he owed to Professor Morris, seeing that the Professor so freely communicated his knowledge in conversation, that it became incorporated with the author's own stores."

Professor Morris was never a robust man, and after a severe

illness about two years since, it became evident that his working-days were ended. His mind, however, remained clear to the last, and his interest in geology never flagged. He suffered more from weakness and depression than from actual pain, and awaited the great change in the calm resignation and confident hope of a Christian.

Though I knew that the end could not be far off, I had hoped that the task of pronouncing this threnody would have fallen to my successor; for there are times in life when the feelings of the heart are too deep for utterance. Those among us who knew John Morris well, need not be reminded of what a friend we have lost. To none is this loss greater than to myself. For years his kindness to me has been almost parental. Nothing that I did or wrote seemed without an interest to him. The main subject of this address was discussed in our last conversation. To the imperfections of my work he was more than "a little blind," to whatever good it might possess he was "ever kind." His death has severed one of those ties which can never be formed again on this side of the grave.

By the death of HENRI MILNE-EDWARDS, not only France but also the whole world of science has lost a veteran of the highest rank, a field-marshal in its army. Born at Bruges in the year 1800, he early manifested a predilection for science. His father was a Jamaica planter, who in consequence of political troubles quitted that island, and after residing for a time in England settled in Belgium. His mother was an Englishwoman, Elizabeth Vaux, a member of an old family; and Henri, the second offspring of that union, was the twenty-ninth child of his father, who had been previously married. The latter, though he had suffered severely from the tyranny of the first Empire, afterwards became a naturalized Frenchman, and his son Henri studied medicine at Paris. For a time art and pleasure proved more attractive to the young man than science; but a loss of fortune summoned him to earnest work. In 1832 he was appointed a Professor at the Collège Henri IV., and twelve years later succeeded Geoffroy Saint-Hilaire at the Sorbonne. Though the major part of his numerous publications belong to zoology, yet palæontology was rightly regarded by Milne-Edwards as an inseparable part of that science, and geology claims him as one of her greatest benefactors. His first paper which directly treats of fossils dates so far back as 1836, and deals with some forms belonging to the genus *Eschara*. He also wrote at various times on fossil Crustacea, and in 1863 on the human jaw of Moulin-Quignon. But his great palæontological work by which his name will ever be held in honour among us, was done among the Corals. Of it the most important parts are numerous papers, written conjointly with M. Jules Haime about the years 1848 and 1849, which were followed up by their great book 'Monographie des Polypiers Fossiles des terrains Paléozoïques, précédée d'un tableau général de la classification des Polypes.' Next in order came, by the same authors, the important contributions to the Palæonto-

graphical Society, on the History of the British Fossil Corals. Of this memoir, so familiar to all English students, the first part appeared in 1850, and the last in 1854, the whole forming a quarto volume of more than 300 pages and 72 plates. Lastly, after the death of M. Haime, Professor Milne-Edwards published his 'Histoire naturelle des Coralliaires,' which, though more strictly zoological than the others, is of hardly less importance to palæontologists from its bearing on the anatomy and on the principles of classification of the Zoantharia. Its merits and that of the preceding work are by none more esteemed and acknowledged than by Professor P. M. Duncan, the author of the 'Supplement' contributed to the Palæontographical Society. Of the enormous amount of work accomplished by Milne-Edwards during his long and laborious life, space does not allow me to speak in detail. I will only say that its leading characteristic was that he never lost sight of physiology in zoology, and thus was a contributor to the philosophy no less than to the taxonomy of science.

His merits happily were not unrecognized. He was revered by his numerous pupils. Many honours were conferred upon him in his own country, among them being the membership of the Academy of Sciences and the grade of Grand-Officer of the Legion of Honour. He received eleven orders from various foreign countries, Great Britain, it is needless to say, not being one of them; but he was elected a Foreign Member of our Society in 1860, and was Honorary Foreign Member and Copley Medallist of the Royal Society. He died on July 29, 1885.

A veteran in science, whose name brings up memories of a past generation of geologists, was lost to us early last March in the person of General GREGOR VON HELMERSEN, who was elected one of our Foreign Members in 1851. He was an assiduous worker, devoting his attention especially to the coal and other mineral deposits of Russia, on which subjects he contributed largely not only to scientific journals but also to more popular periodicals. A friend of Murchison, and a helper in his work on Russia, General von Helmersen's first paper, relating to the Ural mines, is dated in 1835; and he afterwards contributed more than once to our Journal. So far back as 1873 we find a list of sixty-nine papers bearing his name in the Catalogue of the Royal Society; and his latest presentations to our Library in the year 1883, 'Studien über die Wanderblöcke und die Diluvialgebilde Russlands,' and 'Geologische und physico-geographische Beobachtungen im Plonezer Bergrevier,' are a proof of the wide extent of his interest in our science and his ability to labour effectively up to a very advanced period of life.

GIUSEPPE DI TOMASO PONZI, Foreign Correspondent of the Society since the year 1863, was born on May 20, 1805. Educated for the medical profession, he was in active practice for some years, highly distinguishing himself for his energy during an outbreak of cholera in 1836. After devoting himself more especially to scientific pur-

suits, he was still able to be of great assistance to the wounded during the defence of Rome in 1849, and in consequence was for a time regarded with disfavour by the restored Pontifical authorities. Gradually he was attracted from anatomical to geological studies, and after he had taken a leading part in drawing up a geological map of the Roman Campagna, was appointed, in 1862, professor of geology. He was enabled to labour on till within a short time of his death, and was the author of more than ninety papers on various geological subjects, the last, "Contribuzione alla Geologia dei Vulcani Laziali," evidently intended as the beginning of a series, appearing in the 'Atti dell' Accademia dei Lincei,' for 1885.

Passing now from these memories of the past to less painful subjects, I am glad to be able to congratulate the Society on the marked improvement in its finances. This, however, is due, not so much to an increase in our income as to the diminished expenditure on our 'Quarterly Journal,' the sum expended on the last volume having been £776 as against £1106 in the preceding year. One cause of this reduction, no doubt, is that the number of papers read before the Society was less than in the corresponding time of previous years; but I think that the imperative need of economy has also led Referees and Council alike to impress more strictly upon authors the advantage of terseness, and has compelled them to consider more closely whether a paper had a local or a general interest. I believe that in the future, until our income increases, this question must be more closely regarded than it has been in the past.

In what I am about to say I must be regarded as speaking on my own responsibility; but as it is a point which has been forced upon my consideration during my period of office, both as Secretary and as President, I shall venture to touch upon it at parting. At our present rate of income, I am of opinion that about £800 is the maximum sum which we are justified in devoting in any one year to publishing our Quarterly Journal. It is evident, therefore, that some of the papers read before the Society must be issued in an abridged form, occasionally only as brief abstracts. Selection being thus rendered necessary,—even supposing that authors have done their best to prune away redundances and unimportant disquisitions—this must be made on some definite principle. Papers on geological subjects, it appears to me, can be broadly divided into two classes, those of which the interest is mainly local, or those in which it is mainly independent of a locality. Thus, to take an example from our own country, a paper may contain an account of sections which it is highly desirable should be recorded in the transactions of a local society, as adding to the detailed knowledge of a particular formation or district, but which, as telling of no new facts of importance, and suggesting no new inductions, have not sufficient general interest for our Journal. In maintaining such a distinction there is no real hardship to authors; there are now several publishing societies, as well as the 'Geological Magazine,' a function of which is to relieve the pressure on our Journal by providing authors with opportunities

for publication. To take another example from palæontology—a new species may be well worthy of description, but it may add so little to our knowledge that an account of it may justly be excluded from our Journal at times of pressure. This same principle of division applies also to the publication of papers descriptive of the geology and palæontology of distant parts of the earth. Some of these papers have an interest independent of their locality. One that supplies an important link missing from the chain of life; one that aids us to a right understanding of the action of natural forces, or of the genesis of rocks, finds, like the brave man, a fatherland in every country; but the interest of a large number may be said to vary inversely as the distance from any place, so that while they would be of high value in the pages of some antipodean journal, they can only find a welcome here in a season of redundancy of wealth or scarcity of papers. It may be alleged with truth that we have subscribers resident in all parts of the earth,—still, this is the Geological Society of London, and in Great Britain the large majority of our Fellows live and work. It is equally true that the Empire of England is world-wide, and on this account, I have heard it asserted, the capacity of our Journal should be as all-embracing,—sentiments admirable in themselves, and admirably suited for the platform of the orator; but even patriotism, when translated into action, needs the sinews of war, and sentiment must be limited by the homely duty of paying your debts. Hence, I think the Council could not be blamed were it sometimes to suggest to an author, resident in another hemisphere of the globe, that his communication would find a more appropriate birth nearer to the place of its conception. Obviously, hard and fast lines cannot be drawn; difficulties will arise, and authors and referees will naturally sometimes differ in opinion. Still I believe that it is always better to endeavour to establish and to act on a principle, even if this has to be a little elastic, and I am convinced that some such principle is becoming absolutely necessary unless our income increases, at which solution of the difficulty no one would rejoice more than myself. It would, at any rate, I am convinced, save trouble ultimately if such a principle were recognized and professed; for during the last eight years, I can remember more than one case where valued contributors have been annoyed because the Council could not undertake the publication of a paper, when, had there been any general understanding of the kind which I have mentioned, the authors would have perceived that the paper was one to which, under existing conditions, our funds could not properly be applied.

The papers which have been presented to the Society since I had the honour of addressing you last year have been fewer in number, but certainly not inferior in importance, than those which I then reviewed. Among these communications on Palæontology and Stratigraphy have decidedly predominated. In Palæobotany we have received papers only from Mr. Kidston and Baron von Ettingshausen, while our knowledge of many of the classes in the extinct animal world has been augmented. Mr. Vine has written on the

Foraminifera and Polyzoa of the Cambridge Greensand, Mr. Waters has described some Cyclostomatous Polyzoa from Australia; corals have received notice in two papers from Professor P. M. Duncan and in one from Mr. Tomes; and the former author also favoured us with a most important and suggestive paper on the structure of the tests of the endocyclic Echinoidea. Professor Rupert Jones has largely added to our knowledge of fossil Ostracoda. The Mollusca, however, have received only passing notice. Mr. J. W. Davis has described some fish-remains from New Zealand, Mr. Hulke has described the sternal apparatus of *Iguanodon*, and Mr. Lydekker a crocodile from Malta; Dr. H. Pohlig has sent us some notes on extinct species of Elephants and on the Pliocene of Maragha in Persia; and from Mr. Lydekker we have also received a paper on mammalia from the same deposit, besides a third paper on an *Erinaceus* from the Miocene of Switzerland. Dr. H. Woodward communicated to us an important memoir on *Rhytina gigas*, exterminated through greed of gain in historical times; while Sir R. Owen, though unfortunately unable during the past year to be present at our evening meetings, has assured us of his continued interest in the Society by sending a paper on the premaxillaries and scalpriform teeth of a large extinct Wombat.

Our knowledge of the stratigraphy of the United Kingdom has been augmented, as regards the Lower Palæozoic rocks, by Messrs. Marr and T. Roberts, whose important paper on a district near Haverfordwest supplies much valuable information. The late Mr. D. C. Davies wrote on the coalfields of North Wales and Salop; Mr. Bather on the Lias and Oolite of Fawler; and Messrs. Jukes-Browne and Hill, in their recent papers, have augmented our knowledge of the subdivisions of the Chalk and their horizontal extension. From Mr. Irving and Mr. Hudleston we have received important papers on the geology of parts of Surrey; Professor Judd has given us, in a supplementary paper, the final results of the unsuccessful boring for water at Richmond; and Mr. W. Whitaker, in his contribution to the deep-seated geology of the London basin, has supplied students of the physical geography of bygone ages with fresh materials, chiefly obtained in borings for water through the Chalk at Chatham. The rapid thinning out of the Upper Neocomian of Kent and Sussex in a northerly direction, and the occurrence next below it of Oxford Clay underneath Chatham, are facts not less important than suggestive. In Post-tertiary geology contributions have been made by Messrs. Ormerod, Ricketts, Mellard Reade, and J. A. Brown, and last, but by no means least, by Dr. Hicks and Mr. W. Davies, of whom the former has temporarily deserted his researches among the most ancient rocks to explore the bone-caves in the valley of the Clwyd. We have also received papers descriptive of South-African geology from Mr. Penning, and of New Zealand from Captain Hutton; while Dr. R. von Lendenfeld has asserted that even torrid Australia has endured a glacial period.

Petrological papers also have by no means been wanting. Mr. F. Rutley has read us two papers, brief but elaborate; Mr. Cole

has written on hollow spherulites ; Mr. Gresley on some interesting nodules of hæmatite found in the Permian beds of Leicestershire ; your President on some Pierites ; and Mr. Johnston-Lavis has dealt with a large subject in his paper on the physical conditions involved in the injection, extrusion, and cooling of igneous rock. Dr. Callaway has brought to our notice, in his communication on granitic and schistose rocks in N. Donegal, one of those areas on the Western side of Ireland in which, I am convinced, a rich harvest yet awaits future workers. Mr. W. W. Watts has made his *début* as a contributor to our Journal with a very valuable paper on the igneous and associated rocks of the Breidden Hills ; while from Professor Judd we have received another instalment of his long and arduous labours in the North of Britain, in the form of his most important and suggestive memoir on the Gabbros, Dolerites, and Basalts of Tertiary age in Scotland and Ireland.

Without the limits of our Journal also there are no indications that the store of scientific energy on the part of our Fellows is becoming exhausted. The Geological Magazine continues its useful career and maintains its high standard. Perhaps a marked increase in the number of contributors might cause, through an "embarrassment of riches," some anxiety to its excellent editor ; but I am sure that both he and its publisher would regard with equanimity, nay, welcome heartily, a doubling of its subscribers. The annual volume of the Palæontographical Society, edited by our Treasurer, Professor Wiltshire, has just appeared. In it Mr. Starkie Gardner concludes his notice of the Conifers of the British Eocene, and two other works are completed, the authors of which have now laid down the pen for the last time : these are Dr. Davidson's supplementary memoir on the British Brachiopoda, and Dr. T. Wright's monograph on the Ammonitidæ of the Lias. A memoir on the Stromatoporidæ is commenced by Professor Nicholson. It is evident, from the part now issued, that an exceptionally difficult, but certainly very interesting subject has fallen into most competent hands. The present volume maintains the high standard of those that have preceded it, and I know of no other desideratum for this series than a larger measure of pecuniary support. In regard to these two works, may I be permitted for one moment to plead, as I am accustomed to do elsewhere for various beneficial objects, and to recommend them to geologists as worthy of a more general support than they at present receive. Science, like a fatherland, calls for patriotism on the part of its votaries. There are in each branch of science certain publications the support of which is incumbent on the student as a primary duty. Therefore, whether or not his own particular investigations have much in common with these, he is bound, in my opinion, to subscribe to their support, and to devote each year a small sum of money to the general good. It is, I think, hardly creditable to a geologist who can afford the expenditure, to reckon on consulting the numbers of the Geological Magazine and the volumes of the Palæontographical Society in this Library.

The second volume of Phillips's 'Manual of Geology,' rewritten

by Mr. Etheridge, has now been published, forming a book yet larger than the first volume, the work of Professor Seeley, which I noticed last year. This book, as might be expected, is a perfect mine of information on Stratigraphy and the Life-history of the Earth, presenting us with the outcome of many years of incessant labour. Perhaps its magnitude will make it less serviceable to the ordinary student preparing for examinations, but it will be an invaluable book of reference for those who have left behind such anxious periods of trial, and a veritable quarry from which teachers for years to come will extract valuable materials for the edification of their hearers. Notwithstanding the pressure of his official duties, Dr. A. Geikie has found time to prepare a revised and enlarged edition of his excellent 'Text-book of Geology,' and only yesterday I received a copy of another work from his pen, a 'Class-book of Geology;' Professor James Geikie also has just published a smaller volume entitled 'Outlines of Geology,' which will, no doubt, be useful to less advanced students. The first volume of another important text-book has also recently appeared, from the pen of the worthy successor of Buckland and Phillips in the Oxford chair, our friend Professor Prestwich. The present volume treats of geology, chemical and physical. It has a special value as embodying the experience of a veteran in science, and a special interest as being conceived in what we may call (I trust without offence) a reactionary spirit, being intended as a gentle protest against the too monotonous views of some disciples of the Uniformitarian School. Clearly and attractively written, admirably "got up" by the Clarendon Press, this work will add to the reputation, already so great, of its author, and when completed will have a permanent and honoured place in the libraries of geologists.

Our own Library has received many valuable additions, by purchase, exchange, and donations, during the past year, and I hope that, in future, it will be found possible to expend a slightly larger amount on its sustentation and augmentation than has been done in the past. I cannot close my remarks on the recent history of our Society without adverting to the loss which it has sustained within the last few days by the death of Mr. W. W. Leighton, who, for many years, has so efficiently discharged the duties of clerk. He was present among us, as many of you will remember, at our last evening meeting, apparently in good health. He retired to rest as usual that night, and in the morning was found to have passed from slumber into the sleep of death.

Three events during the past year, though only indirectly connected with our Society, call, I think, for a passing notice. Of these, one is the celebration of the coming of age of the 'Geological Magazine,' to which I alluded in my last address. Some friends of the learned and indefatigable Editor-in-chief having decided to avail themselves of the opportunity of indicating their sense of his services to geology, a committee was formed and a subscription-list was opened. As the result, in the month of December last, by permission of the Council.

a meeting was held in this room, at which a service of plate and a cheque for about £250 were presented to Dr. Henry Woodward.

The next is the visit of the Geologists' Association to Belgium. There is no Society in which our own should feel a deeper interest than in this, for it develops an interest in geology, besides sending on many of its members to augment our ranks. Its annual summer excursions have long been a special feature of the Association; it has once before crossed the "silver streak" to the vicinity of Boulogne; but this year it was determined to take a bolder flight and spend a few days among the Palæozoic rocks of Belgium, along the course of the Meuse. The careful preparation for this journey, as evidenced by the publication of geological information, the excellent organization of the expedition, and the cheerful cooperation of some of our Belgian friends, rendered this excursion, in which more than seventy members took part, a remarkable success, on which the President, Mr. Topley, and the indefatigable Secretary, Dr. Foulerton, are to be congratulated. May we hope that some of our own interesting localities will prove attractive to foreign societies, and that our visitors will meet with a welcome as cordial from the geologists of Great Britain?

The last event on which I will touch is the interesting exhibition of maps, models, and teaching-appliances in geography, recently opened under the auspices of the Royal Geographical Society. The main object of its promoters was admittedly to awaken an interest in and improve the teaching of geognosy, or *Erdkunde* (sometimes called physical geography), as a branch of education, especially in our schools and universities. Perhaps, were we disposed to be critical, we might say that some of its promoters, in their enthusiasm, appear to have forgotten that almost all that is truly scientific in what is called physical geography, is really, and has been from the first, an integral part of geology, so that no geologist can concede that geognosy is exclusively or even mainly the property of a Society which admittedly deals with the descriptive rather than with the inductive side of phenomena. This seeming but unintentional aggression, an oversight proceeding from zeal in itself laudable, we can afford to let pass, with just a friendly word of protest, and in every endeavour to secure sound and effective training in a subject so well suited for educational purposes as is geognosy we should cooperate heartily with our sister Society. If its Fellows can provoke British workmen to emulate those of other countries, and provide us with better maps at a moderate cost, and with more systematic appliances for teaching, if they can introduce a more general use of maps with contour-lines and properly graduated shadings, if they can impress upon teachers the value of models, and provide them at a reasonably low price, we, as geologists, can hardly be too grateful.

It is my intention to-day to trespass on your patience by making some remarks on the group of rocks usually designated "metamorphic."

For more than a quarter of a century I have spent some weeks, almost in every year, in districts where crystalline rocks predominate. At first my attention was chiefly directed to physical questions, then to the petrology of igneous rocks, nevertheless I did not wholly neglect those commonly called metamorphic. These, by degrees, attracted more and more notice, especially in the year 1875, when I examined parts of the Pennine Alps, in the districts around the Matterhorn and Mont Blanc. Even then my researches were *lithological* rather than *petrological*; but soon afterwards wider questions began to force themselves more and more upon my mind, and my examination gradually became more systematic.

The first work undertaken in the hope of throwing any light on the questions to which this address will be devoted, was in the summer of 1878, when, on my return from Italy, I examined the rocks of the St. Gothard Pass from Airolo to Göschenen. During the next two years I was able to pay brief visits to parts of the Eastern Alps, the Odenwald, Ross-shire, and Anglesey, and since then I have examined, as you know, other districts in Great Britain. In 1881, I did some work on both sides of the upper part of the Rhone Valley and on the southern slopes of the Simplon Pass. In 1883 I revisited the St. Gothard and studied the interesting sections of the Val Piora, besides crossing (in unpropitious weather) the Oberland Chain on its western side, near where the schists and gneisses begin to be concealed beneath masses of Secondary rocks; after which I passed along a portion of the crystalline series, in a similar situation between Im Hof, in the Haslithal, and Wasen, on the St. Gothard road. In 1884 I examined the metamorphic rocks of Canada about Côte St. Pierre, Templeton, and St. Jerome, and traversed a long section of Laurentian and Huronian rocks*, exposed in the new cuttings of the Canadian Pacific railway, north-east of Lake Huron. Last year I determined to attempt to piece together all the odds and ends which I had gathered in the course of either study or personal work in the Alps, by running two long sections transversely across the chain, so directed as to link together some of my former work and to give me the opportunity of regarding certain questions in the light of the most recent information and hypotheses. On this occasion I had the good fortune to be accompanied by my friend the Rev. E. Hill, to whom I am indebted for much kind aid. We commenced by examining the crystalline rocks of the valley of the Reuss, below Wasen (which previously I had only seen very imperfectly), so as to extend northward the St. Gothard section. Then, passing up the Maderanerthal, we examined

* I gladly take this opportunity of returning my hearty thanks to Sir W. Dawson, Dr. Selwyn, Dr. Harrington, and other Canadian friends who accompanied me and aided me with their knowledge on these journeys, and to the Directors of the Canadian Pacific Railway for their great liberality and the exceptional facilities which they afforded me.

the crystalline series as it emerged from beneath the Mesozoic strata. Turning southward we next went by the Brunni Pass to Dissentis, in the Upper Rheinthal, and thence crossed the Lepontine Alps by the Lukmanier. From the top of this pass we crossed over into the Val Piora, thus examining again some of the work done in 1883, and linking it on to the present section. From Olivone, which stands at the foot of the steeper part of the Lukmanier Pass, we descended the Val Blegno to Bellinzona, whence we travelled to Lugano, following the crystalline schists till they disappeared under Triassic rocks on the shores of that lake. This section completed, we made our way to Ivrea, at the mouth of the Dora Baltea, ascended that valley to Aosta, crossed the St. Bernard to Martigny, and finished by examining, not for the first time, a part of the northern crystalline axis together with the remarkable overlying conglomerate of Carboniferous age at Vernayaz, in the Rhone Valley.

I have risked the charge of egotism in giving these personal details for two reasons. One, because this general sketch will facilitate reference later on to the various facts which I have learnt during my journeys; the other, because I wish to show that, if I express a decided opinion on any point, it has not been formed without considerable labour and an honest endeavour to qualify myself for the work. Here I may venture to repeat, with increased emphasis, the remarks which I made last year as to the importance of accumulated experience in forming conclusions in regard to petrology, a thing true in working at metamorphic rocks even more than igneous rocks. It is often almost impossible to express in words the appearances, whether under the microscope or in the field, which may be absolutely convincing to an experienced worker, and which, notwithstanding, even if they could be actually exhibited to an inexperienced petrologist (however great his skill in other branches of geology), would probably speak to him in a language which would be but imperfectly understood. All departments of geology have their difficulties, but in none, I think, are they so grave as in this part of petrology. Many a time have I felt tempted to despair, so vast did the task appear, so hopeless the problems which it presented for solution. It is very easy to strike out brilliant hypotheses if you will only limit your field of study. The chemist who confines himself to his laboratory, the lithologist whose eye is glued to his microscope, the field-geologist who is vowed to total abstinence from that instrument, in turn put us to temporary shame by the seeming clearness with which they elucidate our difficulties; but, as our experience widens, the guiding star to which they so confidently pointed proves to be but an *ignis fatuus*, and the theory which once pranked it so bravely is ignominiously dismissed to the limbo of exploded hypotheses.

Yet more, I do not believe that the study of any one district, however conscientious that study may be, will suffice. Each region has its peculiarities, which, while they are liable to mislead us on some points, may clear up our difficulties in regard to others. Hence a comparative study of several districts will often enable us to avoid erroneous inductions, or to feel a confidence in our conclusions which would be unattainable with a more limited experience. When a

certain stage of knowledge has been reached, even hasty traverses of a district, which are much to be deprecated at an earlier period, become of the highest value. For instance, there are portions of the Alps in which I should now learn more by walking along the chain in a zigzag course over four passes, than I should by spending the same time in the minute scrutiny of any one of them; because in the latter case I should probably only obtain additional instances of things already known, while the former would enable me to draw some general conclusions.

In this address I shall not attempt to lay before you a tithe of the evidence on which some of the statements which I may make are founded, because to enter upon minute details like those of microscopic work would expand it beyond all reasonable limits; and because, as I have said, they would fail to appeal to many of my audience. It will be my endeavour to give, as briefly as possible, a sketch of the nature of the answers which my investigations have returned to certain questions which, though they did not arise quite simultaneously, were ultimately prominent in my mind. These questions were the following:—

(1) What connexion is there (if any) between stratification, cleavage, and foliation?

(2) What are the relations between the rocks commonly considered of igneous origin and those presumably of sedimentary? Do members of the one class ever pass into the other? Or, in other words, are we right in regarding the former as the result of metamorphic action on the latter, carried to an extreme?

(3) Are the rocks commonly called metamorphic, restricted to any period or periods in geological history?

(4) What is the genetic history of the rocks, commonly denominated metamorphic?

But before attempting to contribute, however inadequately, to the replies to these questions, I must venture a few remarks upon the nomenclature of this branch of petrology. Last year I commented upon our difficulties and deficiencies in this respect as regards igneous rocks; but the confusion which there prevails is small in comparison with that in the present department.

For instance, two words of primary importance, *metamorphism* and *schist*, are as yet far from being used in a definite sense. One geologist will speak of the rocks of a particular district as “metamorphic,” or exhibiting “regional metamorphism,” when they are only silky slates and indurated grits, which may perhaps be termed quartzites: rocks, that is to say, in which subsequent chemical change has utterly failed to obliterate the indications of an original clastic condition. Another will mean by the phrase that the rocks are gneisses and crystalline schists (micaceous, hornblendic, &c.); that is, rocks in which the original constituents have been practically effaced by subsequent chemical changes. Again, in the mouth of one geologist, a “schist” will mean any rock that has a rough fissility,—probably not a shale, but either an imperfectly cleaved slate or a foliated rock; while another restricts the term to the foliated rocks, in which, as a rule, no obvious traces of the original

constituent particles remain. In reference to the lax use of the word metamorphism, I am of course aware that any one may argue in defence that a cleaved argillaceous rock is metamorphic, because it has undergone a change in structure; but in that sense almost every limestone and a great many other ordinary sedimentary rocks are metamorphic, for their present condition is far from identical with their original one. But if the term be thus widely extended, if it is made to include rocks the genesis of which, according to the ordinary laws of reasoning, is a certainty, and rocks the genesis of which is a matter of great uncertainty, then it ceases to have any classificatory value, and cannot be used in any process of exact reasoning. So also as regards the term "schist." I am, of course, aware that, etymologically, the word means something that splits; that, historically, it has been applied variously. But so long as there is no flagrant violation of history or of etymology, objections of this kind are mere trifling. Cases arise in the history of all sciences when it becomes necessary to fix with precision the meaning of a term previously used rather vaguely. So long ago as 1862 the late Prof. Jukes pointed out the necessity for doing this with the word "schist," and I have no hesitation in saying that until both it and "metamorphism" are properly defined, our progress will be greatly retarded. Unless it be preferred to exclude the term from science and coin a new one, rocks should be called metamorphic when such marked mineralogical change has taken place that their original condition is a subject for inductive reasoning rather than for simple observation. A hard-and-fast line cannot be drawn; but, as I pointed out last year, if this difficulty is to stop us we may as well abandon most branches of natural science. Even assuming (for the purposes of argument) that you can discover every stage of transition between a shale or a slate and a mica-schist, still there do exist in nature two great groups at the opposite ends of your chain, each as common as the connecting links are rare, namely, the non-metamorphic shales and the metamorphic crystalline schists (to mention no others); and for these two, as a necessity of clear thinking and definite reasoning, we must have distinctive names*. The same precision is required in using the term "schist." If I do not know (as very often I do not) whether a writer means by schist only a hard rough shale, or a badly cleaved slate, or a foliated (and so truly metamorphic) rock, how can I either understand his reasoning or venture to draw any inductions from it? Nay more, this ambiguous terminology is often, if I mistake not, the cause of erroneous reasoning. I have seen more than once in geological text-books and papers not only statements and arguments with regard to general principles, but also conclusions relating to metamorphism, which I happened to know rested mainly, if not wholly, upon these wide and loose applications of the above terms.

It may, indeed, be alleged that the epithet "metamorphic," as above defined, is too vague to be of any use; and terms, which de-

* To the above-named connecting forms the term "hypometamorphic," proposed first, I think, by Dr. Callaway, may be conveniently given.

fine more precisely the nature of the change, have been suggested. Messrs. King and Rowney, for example, have proposed to divide metamorphic rocks into two groups, *mineralized* and *methylosed*; the one denoting those in which the original constituents have formed, by crystallization, various definite minerals; the other those in which the constituents have been changed by chemical reactions. For the latter process the terms *metasomatosi*s and *paramorphosis* have also been proposed by certain other authors. Further, Mr. Kinahan has proposed to apply the term *paroptesis* to the effects produced by contact with intrusive masses of igneous rocks, and *metapepsis* to the effects of "regional metamorphism." I doubt, however, whether the more high-sounding *paroptesis* is better than the plainer "contact-metamorphism," and it is at least not more accurate; neither do I think *metapepsis* any particular gain. I believe that if it were necessary to distinguish the various modifications comprehended in the general term metamorphism, the following would be the most accurate:—

(1) *Metastasis* (change of order), denoting changes rather of a paramorphic character, such, for example, as the crystallization of a limestone, the devitrification of a glassy rock. (2) *Metacrisis* (recombination), denoting changes like the conversion of a mud into a mass of quartz with mica and other silicates. (3) *Methylosis* (change of substance) denoting change rather of a pseudomorphic character. Under these terms, I believe all the principal changes which we have to consider would be included; but I must confess to no great love for augmenting the technical terminology of science. A compound word of foreign origin is no doubt sometimes a gain, by serving as a brief symbol to express a complex idea; but there is always a danger lest it should be used to mask ignorance rather than to facilitate reasoning.

Minor, but important requirements in our nomenclature are:—The definite recognition of groups where the changes are mineral, rather than structural; namely of metamorphic rocks, in which the new constituents have not, as in the case of the foliated rocks, a definite orientation. Obvious examples are quartzites and crystalline limestones, which, indeed, like argillites*, may be sometimes more properly reckoned among the hypometamorphic. With these cases, however, we are familiar; but it is less clearly understood or admitted that every igneous rock has, or may have, its metamorphosed representative. Thus luxulyanite and greisen result from the alteration of granite; diabases and certain hornblendic rocks from that of dolerite; serpentine (such as the Lizard) from that of a peridotite. Many of the compact felstones also have resulted from the devitri-

* This term is itself not of uniform application. It would best be used for the much-indurated argillaceous rocks which, were they cleaved, would be called slates. The more siliceous varieties are sometimes called *hülleflintas*. This name, though useful for field-purposes, as an admission of incomplete knowledge, is worthless for classification, many so-called *hülleflintas* being merely compact felstones or old rhyolites. As the etymology of the word promises, it has often been the means of leading geologists astray.

fication of once glassy acid lavas, and we are at present unaware how far this alteration has extended. Again, there are many deficiencies in our terminology which need to be supplied. The majority of our names for members of the metamorphic group imply the existence of foliation, yet we not unfrequently meet with rocks in which, though no orientation of the mineral constituents exists, the structure differs generally from those characteristic of igneous rocks, and agrees with those characteristic of metamorphic.

It is no part of my present purpose, for it would lead too much into a discussion of minute details, to propose a system of nomenclature. I shall accordingly content myself with indicating the principles on which such classification should be founded. For this purpose, as I pointed out last year, we may regard the igneous rocks as primordial, and the others as derivative. The latter originate from the former, either directly by some process of detrition, the result being what are called the clastic rocks; or indirectly by separation of constituents, mainly by chemical action, and subsequent precipitation. To the second of these groups belong (for instance) such rocks as beds of anhydrite, gypsum, and rock-salt, with certain limestones and possibly some dolomites. To the first belong the great bulk of the stratified rocks. The igneous rocks also may undergo alteration, either by simple chemical change, as in the instances quoted above, or by mechanical crushing, followed by chemical changes. The results of the latter process vary much; sometimes the previous history of the rock is evident, sometimes it is dubious. Thus some porphyroids are simply crushed rhyolitic rocks, in which a filmy micaceous mineral has been subsequently developed along the rude planes of cleavage; some "schalsteins" are probably compact basalts that have undergone the same treatment; some amphibolites and hornblende-schists are crushed doleritic rocks, in which greater subsequent changes have occurred. As we shall presently see, any igneous rock may be crushed *in situ*, and the result of subsequent mineral change may almost—nay, locally, may wholly—efface its original constitution.

The clastic rocks may be produced either by the explosive action of volcanoes, or by the detritive action of rain, rivers, sea, &c. The constituents of the former will, of course, be mainly of igneous origin. The latter will be the ordinary arenaceous, argillaceous, or other sediments, which are so familiar to us that I need not delay over them. Lastly there are the rocks whose origin is mainly organic, the accumulations of the remains of plants, or the more solid parts of animals.

These rocks, whether of clastic or organic origin, also undergo alteration varying in amount and in its nature. In the first stage, on the chemical side, there are the micro-mineralogical changes which result in the consolidation of material once incoherent, and the partial obliteration of original structure; on the mechanical side there is the production of cleavage. In the second stage, there is the entire or almost entire rearrangement of the constituents of the rock, so that, as a rule, we can only infer its origin by processes of inductive

reasoning. The agencies producing the change, in all cases where we can ascertain their nature, are heat, water, pressure; the effects of these acting singly, in pairs, or conjointly can be observed in various cases familiar to every student, and it is possible that the same results may be produced by different amounts of each. As a rule, however, we can distinguish as the results of "*contact metamorphism*" the effects which are produced on sediments by the intrusion of igneous rocks; while the term "*regional metamorphism*" is applied to the cases where great masses of stratified rocks, buried deep below others, perhaps also subjected to lateral earth-pressures, have been exposed to the action of a moderately and uniformly elevated temperature in the presence of water. To the action of the latter the great masses of schists and gneisses have been by many geologists unhesitatingly referred. They have been regarded as simply the muds and silts and other sediments, and possibly in some cases the volcanic ejecta, of past geological periods, once more exhumed after a long entombment. Thus at one time many of the crystalline schists and gneisses were unhesitatingly regarded as contemporaneous with strata which, in other localities, teemed with the relics of organisms, and were of Palæozoic or even later age. The last few years have witnessed the growth of a new school in geology. Its members, while admitting the possibility of these identifications, consider that the evidence in their favour has been in so many instances proved to be fallacious, that the *onus probandi* lies on him who asserts, not on him who denies the identification. They also are of opinion that the older race of geologists were probably nearer to the truth when they assigned these great masses of apparently stratified crystalline rocks to an age anterior to that of the earliest member of the Palæozoic period. Thus the crystalline schists and gneisses are now supposed by many experienced geologists to have been produced in those dim ages in this world's history which included the dawning days of life, and in ages yet earlier than these, when on a recently consolidated crust, and in an atmosphere overcharged with vapour, forces, physical and chemical, were more intense in action than they have ever been since. For this period the names of Pre-Cambrian, Azoic, Eozoic, and Archæan have been proposed*.

During the last three or four years, however, the attention of workers has been so forcibly directed to instances of modifications

* The claim of one or other has been advocated in certain cases with some warmth. Into these contests I do not propose to enter, for I cannot feel much sympathy with them. In a question of this kind it seems to me comparatively unimportant what name has the priority of date or who coined it. The main question is, which is most simple and most accurately expresses scientific fact? Judged by this standard, it appears to me that Azoic and Eozoic are the less desirable, as involving theories, though the latter is probably the more accurate, for it must be remembered that the propriety of the term Eozoic is not in the least bound up with the *Eozoon* controversy. It is in the highest degree improbable that there were no living creatures on the earth anterior to the Cambrian period. So that if life began at any time prior to it, the period in the course of which it began—as we cannot hope to fix the epoch precisely—may fairly be called Eozoic. The other two express a definite fact, the antiquity of the series. Pre-Cambrian is the more precise, but I think, on the whole, Archæan preferable.

produced by pressure of great earth-movements, followed by mineral changes, that I note a tendency to revert in some respect to the former position, or rather to affirm that, while admitting the existence of great masses of gneiss and schist of indubitably Archæan age, these may be so interfelted and interfolded with those of later date, so crushed and modified subsequently, that it is impossible to go back beyond the date of the last great mutation which, like a desolating flood sweeping over a land, has effaced the traces of an earlier crystallization or an earlier stratification.

In consequence of this recognition of the effects of pressures due to great earth-movements, it would be found, I think, very convenient to apply the term "*pressure metamorphism*" to cases where the effects of pressure may be recognized with reasonable certainty, and to reserve the term "*regional metamorphism*" for those ancient rocks, occupying extensive areas of the earth's surface, which, whatever be their history, are in all probability by no means in their original condition.

In the study of these questions my views have changed. I believed and taught for years, as most geologists of my age would naturally do, that gneisses and schists were in many cases metamorphosed Palæozoic, if not later rocks. Gradually this faith broke down, not, however, until it had led me into serious blunders*. Then, by degrees, I began to recognize how much greater than I had hitherto supposed were the results of pressure, producing crushing *in situ*, often a rude cleavage, followed by some mineral change. Through not knowing this, I had attributed too much weight to appearances of a fragmental structure in gneissoid rocks, and had inclined to refer some schistose crypto-crystalline rocks to altered tuffs, as in the Sharpley and Peldar Tor rocks of Charnwood, instead of to rhyolitic lavas, crushed *in situ*. My work in South Devon in 1883 opened my eyes a little to the effects of pressure as modifying rock-structures; but unluckily my work in the Alps a few weeks later tended rather to throw me off the scent. The following year, however, convinced me how completely stratification could be simulated by the results of crushing, and prepared me to accept, at any rate in part, the statements of Prof. Lapworth as regards the "newer gneiss" of Scotland, and of Dr. Lehmann as regards the Saxon granulites. Yet, while listening to all who seemed to reason fairly and seek to learn of nature, I have striven to follow no teacher, not even myself, blindly, but to work at these questions, as is right, in the spirit of a sceptic, who, however, believes that truth can be found sooner or later.

Let me say now, once for all, that I make no claim to originality or priority of observation. I am fully conscious of my obligations to the writings of those who have passed away, such as Darwin, Sharpe, Sedgwick, Macculloch, Nichol, and Scrope, and, for information, public and private, to fellow-workers in England and on the

* *E.g.* that of thinking that the Twt Hill conglomerate in North Wales might be a member of the earlier Archæan series, and that the "newer gneiss series" of the Loch-Maree district might overlie the limestone.

continent. To none am I more indebted than to my friends Professors Judd and Lapworth in England, to various workers in Canada and in the United States, and to Heim, Lehmann, and the members of the Geological Survey of Switzerland, whose maps have been of late years of the greatest help to me. Still I have studied nature in regard to these subjects more than I have studied books; because, owing to the difficulty of being quite certain of the sense in which the author was using his words, and the scepticism produced by finding upon how slight a basis of fact important generalizations had been made to rest, I determined at the outset to test everything for myself, and take as little as possible on authority or for granted. If then there is any value in my results, it will be that they have been obtained, as far as possible, independently, and sometimes actually in ignorance of the work of others; *e. g.* I had arrived at conclusions which in certain respects agreed with those of Heim and Lehmann before I had read their books.

My task to-day will be rendered more easy by a few preliminary remarks on the structures of which I have to speak, and a brief outline, in anticipation, of the conclusions to which I have been led. Foliation may be produced, as has not seldom been pointed out, by the action of pressure during crystallization. Thus it may occur in an igneous rock, as a structure produced while the mass is cooling. Of this, however, I do not at present speak; such a structure is often local, and is always abnormal; that is to say, it is a departure from the ordinary mode of crystallization of an igneous rock, in which there should be no definite orientation of the constituent minerals. In these cases, however, the minerals retain substantially the characteristics which they exhibit in the normal rock, into which frequently they pass by almost insensible gradations; indeed, not seldom, the "foliated" structure is more conspicuous macroscopically than microscopically. The great mass, however, of the rocks ordinarily designated "foliated," the normal gneisses and schists, exhibit structures which are not less, perhaps more, conspicuous when seen under the microscope than they are in the field, and to these rocks a sedimentary origin of some kind has been generally assigned. Putting by for the present the question of their genesis, I wish at this stage to distinguish clearly between two kinds of foliation which I have observed, in order that, for the sake of brevity and perspicuity, I may use distinctive terms in my future remarks. In many cases we find rocks of very different mineral character, for example, quartzites and mica-schists, alternating one with another so as to make it in the highest degree probable that they are stratified rocks—indeed, it seems in many cases almost certain that they were once beds of sand, silt, mud, &c., which have subsequently undergone mineral rearrangement. Now in many of these we find that there is a very definite orientation of certain of the mineral constituents; the mica-flakes, for example, in one of these micaceous schists, lie roughly parallel one with another, and with the apparent bedding-planes of the masses. Further, in a number of other rocks of more uncertain origin, as, for example, some of the

older crystalline gneisses, we find a general orientation of the mineral constituents, and a certain striping or banding of the rock, produced by an excess of one or more of these over a zone ranging from a fraction of an inch to at least several feet, which suggests original differences of constituents due to bedding; this structure is sometimes seen to be parallel to highly quartzose, micaceous, or calcareous layers, which are most difficult to explain on any other theory than that of stratification*. In such cases the rock usually is not markedly fissile in the direction of these planes of mineral differences. I shall call this kind of foliation, as it has been already named, *stratification-foliation*, as being in some cases almost certainly, in others probably, associated with stratification. There is, however, another kind of foliation, often more conspicuous in the field, which has in all cases been produced subsequently to the consolidation of the rock, and as the result of pressure, generally lateral; to this I shall give the name of *cleavage-foliation*, a term which has been already used by my predecessor, Dr. Sorby, though perhaps in a rather different sense. I can define it best by describing the mode in which it is produced. When fragmental rocks, such as sandstones or shales, are subjected to great pressure, their constituents are to a certain extent rearranged and flattened out until the mass assumes the structure called "cleavage"†. In like way, as I shall presently explain, crystalline rocks—whether granites, dolerites, felsites, rhyolites—in short igneous of any kind—or whether gneisses, schists, &c., that is, such as usually are called metamorphic—when exposed to like pressure, also assume a cleavage-structure. Modifications of this structure I shall presently describe in more detail; at present it will suffice to say that, according to the nature of the rock, it is preceded in some cases by a great crushing of the crystalline constituents, in others by flexure terminating in rupture along planes approximately parallel. It results from this that we can have not only cleaved granites, felsites, pitchstones, &c., but also cleaved gneisses, schists, &c., *i. e.* that crystalline rocks may undergo a cleavage equally with clastic rocks. Now, in the case of clastic rocks, we occasionally see that in addition to the mechanical modification resulting from pressure, there has been a slight amount of chemical change, evidenced usually by the development of very minute films of micaceous and chloritic minerals, especially along the surfaces of imperfect cohesion. The presence of these filmy minerals gives to the slate a peculiar sheen, a sort of silky or satiny look, which differences it from the ordinary slates, though it obviously is much more nearly allied to them than to any of the true schists. To these belong many of the phyllites, a term at present vague, but which I should like to see restricted to such rocks. The (presumed) Cambrian slates of the Devillien and Revinien series on the Upper

* The word is understood to be inclusive of chemical precipitates.

† For a very able and interesting discussion of the precise nature of this change, I refer to the paper on cleavage read before the British Association at Aberdeen by Mr. H. Harker, F.G.S., and printed *in extenso* in the volume for 1885.

Meuse are typical examples of the rock of which I speak. But in the case of rocks originally crystalline, whether igneous or so-called metamorphic, this superinduced formation of minerals appears to take place more readily, because the original constituents of the rock are favourable to it; certain hydrous micas forming readily from felspar, hornblende from augite, serpentine from olivine, chloritic minerals from black micas, or in some cases from augite or hornblende, &c. In consequence of this a very conspicuous cleavage-foliation may be produced in a crystalline rock which may or may not have exhibited stratification-foliation. In this case, however, the individual minerals are, as a rule, rather minute, *e. g.* the cleavage-surface produced in a granite or gneiss becomes coated with a film of minute flakes of silvery or greyish micas, such as sericite, damourite, paragonite; the exact species being often hard to determine, and of course not always the same. The rock is more or less fissile, often markedly so, parallel with this surface of foliation, and the new mineral structure is often far the most conspicuous to the unaided eye. Yet after all it is frequently very superficial. We may take a slab of rock which appears to be a typical grey mica-schist, but examination of a transverse section proves it to be a true gneissic or granitic rock, cleaved first and then "varnished" by this new mineral deposit. It is this secondary foliation which I propose to call "cleavage-foliation," and to refer to its surface, often one of the most conspicuous in a mountain-district, as the "sheen-surface," to distinguish it from an ordinary cleavage-surface on which there has been no notable amount of mineral rearrangement. The effect of this foliation will, of course, vary with the amount of pressure, the constituents of the rock, and a number of other circumstances. It may impress a distinct foliated structure on a rock hitherto not foliated, or it may coexist with an older foliation; it may cut through the latter at various angles, or it may, if I be permitted the phrase, intensify it; in a word, it will exhibit the same relation to the original structure of crystalline rocks that cleavage does to stratification (see p. 97).

Moreover we remark among the crystalline rocks another result of pressure analogous to that which it produces in sedimentary rocks. In the latter, divisional planes are often noticed, parallel with the cleavage-planes, but of less cohesion, so that the mass assumes a deceptive appearance of bedding. The former also often exhibit what seem to be indubitable indications of bedding, parallel with the cleavage-foliation; but these, on examination, will prove to be quite deceptive. It would be convenient to have a term for this structure: as "false-bedding" is already appropriated, I fear I must take refuge in Greek, and would suggest *pseudostromatism*. Moreover, as crystalline masses, whether from slight difference in coarseness or constitution, or from the existence of joints, are of unequal strength, we find that not seldom the results of pressure are more marked in some parts of the mass than in others; so that beds of mica-schist, apparently interstratified, are locally developed by crushing in a granitoid gneiss; zones also of fine-grained rock with a "slabby" bedding occur, which, at first sight, would be unhesi-

tatingly referred to original stratification, but which can be shown to be only a form of pseudostromatism, the results of a crushing *in situ* of zones of the original coarse-grained rock.

With these prefatory remarks, I proceed to sketch out, as briefly as possible, the results of my examination of certain districts in which metamorphic rocks are largely developed. I will commence with the Central Alps, where, as we shall see, we find excellent illustrations of all the structures noted in these preliminary remarks.

The Alps.

The crystalline *massif* of the Oberland Alps is orographically limited on the southern side by the uppermost parts of the valleys of the Rhine and the Rhone together with the headwaters of the Reuss. On the northern side it is bounded geologically, but not orographically, by Mesozoic strata, with which it is marvellously interfolded, and over which in the middle part its peaks seem to rise almost like breaking waves of the sea. Here the watershed is quite at the northern side of the *massif*. At the eastern and western ends the crystalline rocks, which, in the central parts, constitute summits varying from at least twelve to more than fourteen thousand feet above the sea, gradually decline until they are lost to view beneath masses of Mesozoic rock, disappearing at elevations not exceeding about eight thousand feet above the sea, and often less than half that height, especially at the eastern end. Towards that end the deep gash occupied by the Reuss affords admirable sections. The dominant rock, lithologically speaking, is gneiss. Commencing at the part where the scalpel of nature appears to have made the deepest cut into the anatomy of the mountain mass, namely, in the valley of the Reuss about Wasen, we find the rock for a considerable distance to be a granitoid gneiss, sometimes granular, sometimes very distinctly porphyritic, the felspar crystals being occasionally as much as an inch long. Foliation is generally but slightly marked, being only indicated by wavy micaceous lines; its strike is about W.S.W.—E.N.E.; its dip very high, but on the whole inclining towards the southern side; occasionally flaggy or schistose and more micaceous bands occur with the dominant strike and dip; but the more these are examined, the more doubtful it becomes whether they are anything but cases of pseudostromatism. As we ascend the valley to the mouth of the tunnel at Göschenen and so onwards to the Devil's Bridge and the Urner Loch, the gneissoid aspect becomes very slightly more pronounced; that is, the rock would be readily recognized as a gneiss, though not one of the banded varieties, while below we should sometimes be puzzled to differentiate a hand-specimen from a granite. Micaceous bands, also, of a schistose or a slabby rock, simulating bedding, are perhaps more frequent; until just beyond the Urner Loch, an abrupt change, presently to be noticed, coincides with the expansion of the valley into the open basin which forms a part of the limiting trough already mentioned.

Returning to our former position and descending to Amsteg, we

find the rocks distinctly assume a more bedded aspect; compact glistening schists, for instance, occurring near that village; but even these, in their present condition, cannot be regarded as indications of true bedding. Everywhere in this district, except perchance where there appears some slight local disturbance, the foliation and the apparent bedding have a strike roughly W.S.W.—E.N.E., or a few degrees further from the E.—W. line, that is, one corresponding with the general strike of the elongated area of the *massif* itself. It would thus follow that the rocks exposed in the eastern part of the northern face of the *massif* would probably be among the highest in succession, assuming the coarsely crystalline nucleus to be the oldest; and the less disturbed district, in the lower part of the Gademthal, may, I think, be taken as a suitable place for examination. Here we find the crystalline *massif* emerging from beneath great beds of Mesozoic rock, which crest the right bank of the Gadmer Aa, and occur occasionally in outliers on its left bank. I have examined in passing the crystalline series from Im Hof to the Susten Pass. Everywhere they have a more definitely foliated character than in the district last described. At Im Hof, just beneath the newer series, we find a rather granitoid rock; proceeding then to Muhlestalden, the rock for a time retains generally the same aspect, then becomes more fine-grained and rather more schistose. Near the village we find intercalated in the gneiss a band of white crystalline limestone. It is about four yards thick, dipping roughly at about 50° a little S. of S.S.E. The transition from the gneiss is rapid, occupying, so far as I could see, about 3 or 4 inches; but this was, unfortunately, the most perishable part of the rock. A slight fissility in the marble corresponds with the foliation in the gneiss, and both with the bedding indicated by the former. I do not think it possible that this limestone could be the result of infiltration. As we ascend from this point towards the basin occupied by the glaciers of the Stein Alp we pass over gneisses generally similar to the last described. Now and then these become rather distinctly foliated, and occasionally exhibit an apparent stratification, indicated, for example, by a rather rapid change from a band at least several feet thick, where a dark mica is deficient, to one where it is rather abundant. Again, cases may be noted where the layers of mica have distinctly undergone crushing and corrugation since their formation; and I observed that, on the whole, the rock was less fissile in the direction of a micaceous layer than is often the case among crystalline rocks. As we descend from the summit of the pass towards Wasen we notice similar rocks; but in the neighbourhood of that village (after a very considerable interval in which little or no rock is exposed in the bed of the glen), we come upon the granitoid rock, already mentioned as bordering the Reuss.

The evidence of the Haslithal and of the glens occupied by the two glaciers of the Aletsch (though I do not pretend to have minutely explored the latter, and it is many years since I walked through the former) indicates that rocks similar to those described in the valley of the Reuss extend far away in a W.S.W. direction.

In many places we find, as above, intercalated in the more granitoid masses, bands of mica-schist or of a slabby fine-grained gneissic rock, which might readily be taken for proofs of bedding, but which, on examination, prove, at any rate in many cases, only instances of pseudostromatism; while, as we approach the southern part of the chain, *e. g.* in the neighbourhood of the Eggischhorn and Sparrenhorn, and on their southern slopes, the rocks are generally more distinctly foliated, and clearer indications of bedding are given by definite changes in mineral structure. At the extreme western end of the *massif*, on the way from Kippel to the Lötschen Pass, we come upon sundry chloritic schists, which, I think, must indicate some sort of stratification in the materials of which this central *massif* is composed. These are referred by the Swiss geologists to a newer series. If we examine the Maderanerthal, which occupies a position in regard to the Mesozoic rocks similar to that of the Gadmenthal, and at the head of which we have almost our last view towards the east of the crystalline series, we find at first a rather flinty schistose rock, which, however (like that already mentioned near Amsteg), cannot be relied upon as a proof of bedding, as the rock is evidently greatly crushed, and the conspicuous structure is due to sheen surfaces*. In the upper part of the glen we find moderately fine-grained gneissic rocks, and almost at the foot of the Hüfi glacier, very near to the base of the overlying Mesozoic rocks, we have a most interesting series. Space forbids my entering into details, so that I must ask to be allowed to quote the conclusions at which I arrived after very careful work on the spot, corroborated by subsequent microscopic study:—

(1) We have here two varieties of rock, both igneous in origin: one not unlike the so-called Dimetian of Pembrokeshire, almost a binary compound; the other containing, in addition to quartz and feldspar, a fair amount of hornblende. The relations of these are not now clear; sometimes the former suggests intrusion into the latter; sometimes they seem to graduate rapidly one into the other.

(2) Both contain fragments of a highly crystalline hornblende-schist, often exhibiting a marked mineral banding like some of those at the Lizard, Cornwall. The metamorphism of this rock was evidently accomplished when the dislocation took place, as the fragments lie about in the enclosing rocks in different directions. (A similar hornblende-schist occurs *in situ* at no great distance.)

(3) In close relation to the two igneous rocks is a considerable amount of a gneissose rock. The evidence as to the relation of the latter to the former is not absolutely conclusive; but we have either a case of igneous rocks intruded into metamorphic rocks of very similar composition, or the foliation (which has generally a S.W.—

* In the newly published map of the Swiss Geological Survey, I find that the rocks of the Maderanerthal and of the Reuss valley, up to near Gurtellen, are regarded as an infold of an upper series (Casanna Schists). This may be quite right, but I did not see any evidence which placed the question beyond a doubt.

N.E. strike) is the result of crushing, subsequent to which there have been local disturbances.

It cannot, I think, be doubted that the above group of rocks passes under the Mesozoic series; and no member of the latter indicates any approach to a foliated structure, though a rude cleavage is often conspicuous.

On the south side of the Maderanerthal, mounting to the Brunni Pass, we found gneisses, which were sometimes moderately schistose, at others almost as granitoid as those near Wasen, on the St. Gothard. About 1800 feet above the Maderanerthal hotel was a gneissose rock, which, however, contained abundant well-defined felspar-crystals about 1 inch long, and included fragments of a dark (probably hornblendic) rock. Bands occur of a rock resembling felstone or porphyroid, probably squeezed dykes, and some more distinctly schistose, which, however, may very well be of a like origin. In fact I saw nothing, from the opening of the upland glen leading to the Brunni Pass to beyond the summit, which I could regard as indubitable proof of stratification, though there were occasionally very slabby or schistose bands, as, for instance, at the summit of the Pass; these, however, on closer examination, appeared to be merely crushed-up gneiss, and the surface of conspicuous foliation is only a "sheen" surface. They all show very nearly the same strike, viz. between W.S.W. and S.W., and I may make the same remark of all the rocks which we saw on our descent until within a short distance of Dissentis.

It results, then, that while along the western end and a part of the northern and southern fringe of this huge ellipsoid of crystalline rock there are appearances which are difficult to explain, except upon the theory of some kind of precipitation or stratification of the original constituents, there are none over the inner and greater portion which we can safely trust; but the schistose and gneissose structure, with its uniform strike and high dip, is almost certainly the result of pressure, and thus is an instance of cleavage-foliation.

I turn now to the great trough which bounds this orographic system on the south. Almost immediately on entering the open basin of the Urnerboden, we find a quartzo-micaceous limestone, highly crystalline, intercalated among fissile mica-schists, which are followed by a great series of schists—micaceous, chloritic, &c. These have evidently been modified by the action of pressure, sometimes to an extraordinary degree, subsequent to their becoming true schists; they are in places almost as fissile as slates, and the predominance of "sheen surfaces" has obliterated earlier structures, nevertheless we observe in the outcrops and sections such marked mineral differences among different masses, that it is impossible to avoid attributing them to original differences in the materials of which they are composed. This series is referred by the Swiss geologists to the Casanna schists—a series which, whatever may be its precise definition or geological equivalence, is universally regarded as decidedly more modern than the central gneiss. It can be traced for many

miles, on the one side over the Ober-Alp Pass down the valley of the Upper Rhine, on the other over the depression of the Furka Pass down the Upper Rhonethal to within a very few miles of Brieg*. Infolded with this, upon the western side of the Ober-Alp Pass, is a mass of Jurassic rock, which may be traced from the lower slopes of this pass along the upper valley of the Reuss over the Furka Pass as far as Obergestellen. This series, where I have examined it, consists of a black limestone, often slightly cleaved, which, lithologically, is not unlike some of the darker varieties of British Carboniferous Limestone, and of a satiny black slate. According to the Swiss Geological Map, it is, in one place, associated with the cream-coloured calcareous rock named *rauchwacké* or *rauhwacké*. The schists of the supposed Casanna group, notwithstanding the crushing which they have undergone, are readily distinguishable from the most slaty members of the Jurassic series, so that they are evidently separated from the latter by a vast interval of time.

Bounding, on the southern side, the troughed series of schists mentioned above, rises another mass of crystalline rock, orographically of even greater importance than the last, for it is the watershed of this portion of Europe. The St. Gothard Pass affords one of the shortest and simplest sections of the central part, and its tunnel has given a section yet more complete, which is nowhere quite so much as two miles away from the course of the high road. The Lukmanier on the east, the Gries and Simplon on the west, besides other less familiar passes, afford excellent opportunities for parallel and comparative sections. The northern slopes of the St. Gothard, from a short distance above Hospenthal, where the supposed Casanna group ends, give us a series of mica-schists and micaceous gneisses which, as we ascend, become rather less distinctively micaceous. These rocks, which may be taken as beginning at about 900 feet above Andermatt, and extending to a little below the highest part of the pass (about 2200 feet above Hospenthal), afford us numerous most interesting associations of very micaceous schists with gneiss (sometimes very porphyritic, the crystals of felspar being occasionally well defined and quite two inches in length). At present I will say no more than that we are compelled to adopt one of the following explanations:—either we have here the result of the metamorphism of successive beds of different materials—in which case foliation corresponds with stratification—or a granite has been intruded, often rather uniformly, into a mica-schist (which, whatever may have been its origin, was at that time a mica-schist), and both have been subsequently modified by pressure. The strike of the apparent bedding and foliation is roughly S.W.—N.E., the dip very high, usually inclining somewhat on the S.E. side. The plateau forming the uppermost part of the pass is occupied by the peculiar porphyritic granitoid rock to which the Swiss geologists have given the name

* Of rocks so crushed I speak with much hesitation and deference, but I have sometimes doubted if these may not be newer than the Casanna series, and, at any rate in part, represent the still higher schists of which I shall presently speak.

of Fibbia gneiss. They hesitate whether to pronounce it a granite or a gneiss. It exhibits a slight foliation, which has the usual general south-westerly strike; the larger crystals of felspar, commonly both in hand-specimens and under the microscope, do not show that definiteness of outline which is characteristic of normal granites, and the ground-mass also differs in similar respects. At the same time we occasionally find places where the rock has the aspect of a normal granite; moreover, on examining in the British Museum the collection of the rocks pierced by the tunnel, I have been unable to identify this Fibbia gneiss. Yet, on the St. Gothard Pass, it occupies a belt about 2000 yards wide, measured across the supposed strike, and the line of the tunnel is not more than a couple of miles distant. Hence I am now inclined to regard this "Fibbia gneiss" or "Gothard granite" as a true intrusive granite which has been subsequently modified by pressure. It differs, I may observe, in many marked respects from the more porphyritic varieties of the granitoid gneiss already described in the glen of the Reuss, and has points in common with sundry masses in the more southern part of the Alps which are generally admitted to be intrusive. In descending from the pass on the southern side, we pass over, first, a narrow zone of rather granitoid gneiss, the relations of which to the first-named I have never succeeded in satisfactorily determining*, and then, at a height of perhaps 1500 feet above Airolo, we find some remarkably well-banded gneiss of rather finely crystalline texture, dipping at a high angle to the N.W., and so retaining the old strike. In one set of bands quartz and felspar predominate, in the other mica, chiefly biotite; these bands not seldom exceed an inch in thickness, and I cannot account for them on any other theory than that of some kind of stratification. I may, however, add that the rock had a very compressed look, and recalled to my mind certain sediments (like some at Torcross) which have been exposed to great pressure in a direction at right angles to the bedding. Below this, at no great distance, a series of well-marked schists sets in, and extends down the slopes to a little above Airolo. They are chiefly mica-schists and, as a rule, are distinguished by the conspicuous presence (though in minute individual scales) of a white mica (paragonite), which gives a peculiarly silvery and silky aspect to the apparent surfaces of foliation. These mica-schists exhibit much variation, they are frequently rich in garnet (the crystals being sometimes nearly an inch in diameter), and not rarely actinolitic (the crystals being occasionally two or three inches long); occasionally also the schists are chloritic, and assume a pale dull green tint; now and then we find a band of massive dark hornblende-schist. Without relying upon the presence of the last, and making every allowance for the effects of subsequent pressure (which have doubtless been very considerable), I cannot explain the association of the different members of these schists, often very well-marked bands, except by original differences of mineral composition, *i. e.* by some

* At my last visit the sections in this part were much obscured by the unusual amount of snow.

kind of stratification*. At Airolo we find a yellowish dolomitic rock which I regard as an infolded mass of much more recent date.

I proceed next to the section given by the northern part of the Lukmanier pass. On commencing the ascent from Dissentis, we find a group of mica-schists, the continuation of the trough of the Casanna schists already mentioned, which have obviously been exposed to tremendous crushing, so that the dominant structure is a cleavage-foliation which has a general W.S.W.—E.N.E. strike, and is nearly vertical. Its surfaces are coated with a silvery mica, and the rock breaks into flakes thin as millboard, being so friable that specimens of any size are hard to obtain. As we pass through the numerous tunnels in the glen of the Medelser Rhein we note occasional mineral differences, such as bands of greener schist, one being a well-marked talcose schist about a yard thick, and some of a whiter and more quartzose schist, which has to some extent resisted the crushing. As we ascend, the effects of this become less marked, and some indications are found of an earlier stratification-foliation, which is parallel with the apparent bedding, and is here and there to be distinguished from the dominant cleavage-foliation. Before finally quitting this series of more or less cleaved schists, we pass two masses of augen-gneiss, the second containing crystals of felspar of definite but rather rounded outline, which are sometimes quite three inches long, and lie in different directions in a rather fissile foliated ground-mass. I feel certain that both these rocks are really granite, intruded prior to the great compression which has affected the whole range. Near Casalia we have another augen-gneiss and an infold of *rauchwacké*, evidently a rock of much later date†. We now pass a group of rocks lithologically gneisses, sometimes porphyritic, sometimes very fissile from crushing, until, about a mile below S. Gion, we reach a mass of granitoid gneiss, somewhat resembling the Fibbia gneiss of the St. Gothard. Here, however, there is abundant evidence that the rock is a true granite, intrusive into an ordinary moderately fine-grained gneiss, and that both rocks exhibit a cleavage-foliation resulting from subsequent pressure. This granite, so far as I know, continues till we approach Santa Maria (nearly at the summit of the pass). Generally it is fairly massive, but occasionally it becomes rather fissile. Then occurs one of those singular complexes which, if judged by the ordinary laws of stratigraphical sequence, would lead us to the most extraordinary theoretical results. According to the map and sections of the Swiss surveyors, which I have to a great extent verified on the ground, the granite is succeeded by gneiss, and this by quartzose mica-schists or micaceous quartz-schists. Then comes a slate, assigned to the Lias, then a black mica-schist with melanite garnet, then "*rauchwacké*," then another band of the last-named schist,

* I shall hereafter refer to these as the Tremola schists.

† This, on the opposite bank of the valley, is associated with a very fissile "schist," referred by the Swiss geologists to the *schistes lustrées*, which I was not able to examine. The new map, however, refers it to the Carboniferous series.

then Lias slate, followed by rauchwacké, and then by gneiss. The melanite schist, as I shall presently show, is undoubtedly much less ancient than the gneiss; the position of the rauchwacké is uncertain, but I consider it, not as associated with the melanite schist, but as of much later, probably of Mesozoic age. It is obvious that in any case we have here a region folded and possibly faulted in the most extraordinary way.

The rauchwacké occupies much of the open basin which forms the upper part of the Lukmanier pass. From this the road descends to Olivone, along a valley roughly running E.S.E.; but in order to ascertain the relation of the rocks on the southern slope of the watershed, it will be better to turn aside in a W.S.W. direction and examine the ground between Santa Maria and the Val Bedretto. From Airolo, at the foot of the descent from the St. Gothard, to the top of the Lukmanier pass, as may be seen on the Swiss geological map, a zone extends, occupied by a variety of schists of a well-marked mineral character, together with some rauchwacké. These rocks cross the lower part of the noted Val Canaria, form the right bank of the Lago de Ritom, and then running almost due east crop out along the upper slopes on the southern side of the Lukmanier Pass. From Airolo to a spot about $3\frac{1}{2}$ miles E. of Lake Ritom (a distance of some eight miles in all) this trough is bounded on its northern face by mica-schists, among which the peculiar actinolitic and garnet-bearing schists (Tremola schists)* already mentioned are predominant. A gneiss, which hitherto has formed the northern boundary of the latter schists, then sets in. The southern boundary of the trough (which is mapped as a kind of peninsula from a much larger mass occupying the mountain region on the south side of the Val Bedretto) is formed by gneisses, which, like the above mentioned, are commonly rather micaceous; in these also I have seen (though rarely) calcareous bands. The gneiss on the northern side of the trough, speaking inclusively, is an extension of that dominant on the northern slope of the St. Gothard; that on the southern side may also be fairly regarded as an extension of the same rock. I account for the absence of the Tremola schists by faulting, probably upthrust. This idea, the structure of the gneiss itself, indicating great compression at a high angle with the apparent bedding, fully confirms.

Neglecting the rauchwacké, which I regard as a rock of comparatively late date, I turn to the schists which occupy a part of the above-named trough in the Val Piora, and occur to the south of the Tremola schists. The highest (not in geographical position) is a series of black mica-schists with melanite, interstratified with a light brown felspathic quartzite. Beneath this comes a zone of rather silvery mica-schist, with beautifully developed staurolite crystals, overlying a thick bed of quartzite. These appear to be followed by a series of variable schists, some quartzose, some calcareous, all containing more or less of a silvery mica, probably

* These schists can be traced some few miles at least further west, up the Val Bedretto. The Swiss map gives them a total extension of about 13 miles.

paragonite. The mineral changes among these schists are often so marked that, though I do not assert the apparent bedding to be the true bedding, I am compelled to regard the mass as stratified. In any case it is impossible to explain the succession of the staurolite schist and the underlying quartzite, both thick masses as clearly defined as any beds of clay and sandstone could be, on any other hypothesis than that of an original stratification. In the next series also the evidence is no less strong. Here we have a well-banded series, of considerable thickness, in which the quartzite and the black schist alternate again and again. Now we find a thick band of schist; now one of comparatively pure quartzite; now the two are interstratified in layers varying from two or three inches downwards, the black schist often retaining its garnets, and occurring sometimes in continuous bands merely a small fraction of an inch in thickness. In short, whatever association we are accustomed to see in a dark shale, and a coarser, more quartzose silt, we can observe it here. Commonly the direction of foliation in the schist agrees with the bedding, and the whole mass seems to have been subsequently compressed in a direction perpendicular to the planes of stratification; but now and then the rock exhibits wonderful corrugations, apparently subsequent in date to the mineralization (or metamorphism) of the whole mass.

This peculiar melanite schist* is a member, probably one of the lower members, of a great group of metamorphic rocks which have a remarkable extension and development in the Alps. They exhibit, at any rate in this district, characteristics which can be distinguished, even at a distance; the chief being the dark but rather ruddy brownish colour which they assume in weathering, and their conspicuously stratified aspect. The latter is so marked that at a distance it is not easy to distinguish them from members of the Mesozoic series. Not seldom I have felt doubtful as to their true nature until I had actually taken a specimen in my hand. It then becomes obvious that they are thoroughly crystalline †.

Now this peculiar melanite schist, as I have said, occurs near the summit of the Lukmanier Pass; we find it again in great force (after getting clear of the rauchwacké) on the upper part of the descent towards Olivone; and I have picked it up on the summit of the Gries Pass. I believe it has a yet wider extension, but I confine myself to instances where I have myself collected specimens, the localities of which I can only distinguish by the labels. The first

* Mr. Rideal, Demonstrator of Chemistry in University College, has kindly ascertained for me that the principal colouring-matter of this dark schist is graphite. Iron-oxide and a trace of manganese are also present.

† Their effect on the landscape can be nowhere better appreciated than in the noted view from the Bell Alp Hotel. There we see them clearly in the part of the Pennine chain which bounds the valley of the Rhone, forming its upper peaks on the eastern side, where they occasionally attain an elevation of from 9000 to 10,000 feet above the sea, and they then come sweeping down towards the valley, until, about the foot of the Simplon and the mouth of the Vispthal, they form the subordinate outer peaks and the lower slopes of the range.

two of these localities are more than three miles apart in a straight line: from Santa Maria to the exposures between the Lago de Ritom and the Lago de Cadogna is quite five miles; and from the former lake to the Gries Pass is about fifteen miles—that is to say, this peculiar rock abounds, to my knowledge, at three localities in the line of the general strike of the district, the extremes of which are more than twenty miles apart, and at two localities, the component of whose distance, measured across the strike, is full two miles, if not more. But this is not all. In descending the Lukmanier Pass towards Olivone we again meet with this peculiar melanite schist, overlying various mica-schists, some garnet-bearing, some containing staurolite or kyanite, together with quartz-schists and quartzites, the group recalling in several respects the one already noted as occurring on the right bank of Lake Ritom. As in that neighbourhood, so here, the mode in which these rocks, so different in mineral character, are interstratified and associated, both on a large scale and on a small, seems to me inexplicable, unless it be the result of stratification. They exhibit stratification-foliation, and have obviously been subsequently subjected to great pressure. This, in some cases, has flattened out the foliated bands, as if (to use a very homely simile) a rolling-pin had been passed over layers of tough paste alternating with “jam;” in others has forced them into crumples and zigzags of every possible kind, and has often developed a secondary cleavage-foliation, this last being quite independent of the first one (figs. 1, 2, p. 97). The evidence in favour of these conclusions is, to my mind, overwhelming. Excellent sections are exposed again and again by the roadside for a distance of perhaps a couple of leagues.

Gneiss resembling that described above reappears on the right bank of the Val Campra, and is traversed by the long sweeps of the new diligence-road leading to Olivone. In the Val Grigna, however, which descends from the north to join the Val Campra at this town, and initiate the Val Blegno, we again come upon the great series of brown-banded schists, though here the melanite schist does not appear to be well developed. But the lower part of the Val Grigna, a narrow picturesque glen, cuts through a huge mass of a quartzose rock, sometimes calcareous, interlaminated and inter-banded with mica-schist, generally rather dark, often exhibiting a very distinct secondary or cleavage-foliation, as well as one corresponding with the bedding. Of one westerly extension of this mass I have already spoken, but I may add that in the neighbourhood of and below the village of Binn in the Binntenthal, where it is admirably exposed, it still preserves its main characteristics. A little above the latter village, apparently low down in the series, is a thick band of white crystalline dolomitic limestone. Further, in the cliffs of the Hohnsandhorn, to the north of a glacier pass leading, by the north side of the Ofenhorn, from the Tosa Falls to Binn, we see the following section:—(1) a strong gneiss, rather markedly banded *, (2) a zone of the dark-bedded schists, (3) the crystalline

* This I examined at the top of the pass.

limestone, (4) a second mass of the dark-banded schists. We have here a section of a slightly curved synclinal trough of the bedded schists (2, 3, 4), and foliation appears to agree with bedding, as it certainly does when this series comes down to the valley, dropping more than 3000 feet vertically in rather less than eight miles. I call especial attention to this section, because it can only be explained either as a case of very peculiar overthrust faulting or of unconformity. The characteristics of the gneiss would lead me to refer it as a whole to a lower position than those of the St. Gothard and the Lukmanier, and this reference is supported by my examination of the Simplon Pass further to the east. Hence at this place the Tremola schists (and probably the underlying Gothard or Lepontine gneisses) are wanting.

Turning back to Olivone, we find, as I have said, gneiss rising from beneath the bedded dark schists on the right bank of the Val Campra. This rock crosses the Val Blegno below Olivone. It bears a general resemblance to, and is mapped as continuous with, the Lepontine gneiss described as extending from the lower end of Lake Ritom towards the Val Bedretto. In places it appears to have been subjected to great pressure, which often, but by no means always, has acted at right angles to the original foliation.

Gneiss of this character continues down the Val Blegno (which is now running almost south), but near Aquila is another infolded trough of the brown-bedded schists. Lower down comes moderately fine-grained gneiss, with a fair amount of dark mica, lithologically not materially different from the last described. A little above Ludiano a coarse porphyritic gneiss sets in, the felspar crystals being often from one to two inches long. Notwithstanding the rather rounded outline of these, and the fact that the rock is fissile enough to be used for posts to support the vine-trellises*, careful examination has led me to the conclusion that it is only a porphyritic granite to which a foliated structure has been imparted by subsequent crushing. Alternations of this with a finer gneiss continue for some distance. Then a gneiss more resembling the former type sets in, continuing to Biasca. Here the rock varies from fairly coarse to moderately fine; planes which suggest crushing being universal, and dipping at about 30° to E.N.E.

From Biasca to Bellinzona the rock, as a whole, exhibits so little variation that I did not think it necessary to make a close examination, and thus confine myself to saying that a gneiss which at first closely resembles that of Biasca, extends far down the valley, but after a time becomes more granitoid, and is quarried for blocks as well as for slabs. About Misocco a more schistose character is again evident. After passing Bellinzona towards Lugano there is a decided change in the character of the rock, and here I began again a more minute examination. This rock is a dark mica-gneiss. In the mass it exhibits a gradual mineral change which suggests bedding, but is roughly parallel with a cleavage-foliation. This strikes

* Slabs about 4 inches thick, a foot or so wide, and 6 or 7 feet long, are readily obtained.

between W.N.W. and W., dipping at various angles (not high) on the southern side. To this succeeds a rather less fissile gneiss (which weathers a lighter colour), the dip here being about 50° E.S.E.; then comes a coarser and still less micaceous gneiss, which, however, after a time reverts to much the same type as above. Just above Taverner the dip is high to the east. From this place to the neighbourhood of Lugano road-sections are wanting. Near the railway station of that town highly fissile schists are seen in cuttings. These exhibit a cleavage-foliation, which makes a high angle with the bedding, the latter being indicated by a band of quartzose rock about 20 feet thick. This dips roughly to S. at about 30° ; the cleavage-foliation dipping at about 40° between N.N.E. and N. The "papery" mica-schist reminded me much of that on the Lukmanier road near Dissentis, and I find it is referred by the Swiss geologists to the same group, the Casanna schists. South of Lugano as far as Morcote, similar but less fissile mica-schists are exposed at intervals by the lake side beneath the Triassic strata, and are cut by felstones. These also are referred to the Casanna group, except that at the latter place they are included in the mica-gneiss, like those above Taverner. In short, if we omit the brown-bedded schists and certain considerable masses, which may be crushed granites, the greater part of the section from Olivone southwards, till the crystalline rocks are lost beneath the southern fringe of Mesozoic and later beds, consists of micaceous gneisses or mica-schists, which I should regard, at any rate in part, as belonging to the Lepontine group; and this section is in accordance with what I have observed in other neighbouring districts.

I have been obliged to describe this traverse of the Alps at what may seem an unreasonable length, because I cannot otherwise impress upon you how strongly the evidence, both in the field and in my subsequent examination of specimens, is favourable to a definite succession from the mica-gneiss up to the brown-bedded schists, and to the existence of an earlier foliation, connected with some kind of stratification, and of a later cleavage-foliation which is sometimes less, sometimes more conspicuous, than the other. I shall pass more rapidly over the evidence afforded by the districts further west. In the sections which I have examined on the Simplon road I agree with Professor Renevier in considering the coarse gneiss (called by him Antigorio gneiss, and exposed in the grand cliffs of the gorge of Gondo) as the most ancient rock. This is overlain by gneiss and mica-schists, and in the lower part of the latter group we find the following succession:—(1) fairly coarse gneiss, (2) crystalline limestone about 4 feet, passing into calc-mica schist, about 2 feet, followed by dark mica-schist. In (2) are sparse lines of a dark mica parallel with the apparent stratification, which dips roughly 30° W.N.W. The southern slopes of the Simplon Pass, and a part of the descent on the northern side, are formed of bedded gneisses and mica-schists, probably folded and faulted together in such a way that it will be no easy task to unravel the true stratigraphy of the mass. The Swiss geological map places a long axis of gneiss, of

the second or less granitoid type, as extending from the north flank of the Ofenhorn to Monte Leone, and my examination of these two points led me independently to refer the rocks to the same general series, one to which I should be disposed to assign a rather earlier date than to the Lepontine gneisses of the St. Gothard and Lukmanier. In descending the northern side of the Simplon Pass we traverse the zone of the brown-bedded schists, while close to the Rhone valley there is a dark, slaty, and not much-altered rock, associated with gypsum and dolomite, which is probably a remnant of a trough of much later rock, Carboniferous or Secondary.

In like manner the Pennine Alps about the head waters of the Visp and of other tributaries of the Rhone immediately to the west, in the main consist of a fundamental mass of coarse gneiss, but rarely exposed, which passes up into finer-grained gneisses. To one or the other of these the peculiar Arolla gneiss probably belongs. These are followed by a great group of mica-schists and fine-grained gneisses, which now and then recall to mind the Tremola schists, and these, again, are overlain by bedded green and grey schists—chloritic, hornblendic, and micaceous—which are regarded, I have no doubt rightly, as members of the same general group as the brown-bedded schists already mentioned, that is the *schistes lustrées* of many authors. In this district, towards the S. and S.W., green schists are much more frequent than further east; but it is more than probable that some of them are merely crushed igneous rocks. Others, however, both field evidence and microscopic examination lead me to consider as originally sedimentary.

Passing up the Dora Baltea from Ivrea, and neglecting some rocks obviously of igneous origin, we traverse gneisses which have a general resemblance to those already described on the southern flanks of the Lepontine Alps, and then enter micaceous, chloritic, and other green schists, resembling those of the Zermatt region. The valley of the Dora Baltea, below Aosta, cuts gradually through a great zone of these newer schists, and the road to the St. Bernard does not pass away from it until we are about halfway to St. Remy. Hence to the summit of the St. Bernard and thence to the neighbourhood of Liddes our course lies over schists of a stronger character. Mica-schist is the dominant rock. This is often silvery, but sometimes darker greenish varieties are also found, together with chloritic or actinolitic schists, and fine-grained gneisses. On the southern side of the pass silvery schists, with garnet and with andalusite, are not rare. All these are referred by the Swiss geologists to the Casanna group, and they not unfrequently recall to mind the Tremola schists of the St. Gothard and Val Piora region. On the highest part of the pass there are some "augen-gneisses," but these may be only crushed intrusive granite. The rock also on the northern side has often a more gneissic character than that on the southern. Near Liddes, after passing a trough of Carboniferous rock (which I have not examined), we come to very characteristic grey schist belonging to the Upper (*schistes lustrées*) group; then, after crossing an infold of slaty Jurassic rock, descend to the Rhone

valley down a gorge chiefly consisting of a coarse gneiss followed by strong mica-schist.

The investigations which I have described extend over an area measuring about 85 miles from W.S.W. to E.N.E., and full 50 miles in a transverse direction. It would be easy for me to quote corroborative evidence from other districts in the Alps, but this, I think, will suffice to warrant the following conclusions:—

(1) The oldest rock visible in the above-described districts of Alps is a granitoid gneiss, which gives no evidence of bedding or foliation other than such as may be only the result of subsequent pressure, and which may itself possibly be a rock of igneous origin. It does not, however—as do certain other granitoid rocks in the same region, of a rather different lithological character—exhibit any indications of intrusion that I have been able to discover, but seems to pass up into

(2) Finer-grained gneisses, more rapidly varying their character, themselves occasionally showing a foliation and a mineral banding which it is difficult to attribute to any subsequent modification, and apparently interstratified with true mica-schists, and even with crystalline limestones.

(3) Schists and gneisses, generally rather micaceous, form the next group. The gneisses, which appear to belong rather to the lower part, are commonly somewhat friable; the felspar occurs in small ill-defined granules, and is of porcelain-white colour; under the microscope it is less abundant than we should expect from macroscopic examination. Hence this rock differs much, both in the field and under the microscope, from the gneisses of the preceding group. The schists belong rather to the upper part; mica is the dominant mineral, and a white mica is frequent as well as black; but chloritic and other green schists occur, while garnet and actinolite are locally abundant, as are cyanite, staurolite, and andalusite. Possibly some of these last should rather be included with the next group, namely

(4) Schists of a markedly bedded aspect, sometimes micaceous, sometimes (though more locally) chloritic, actinolic, or talcose, interbedded with calc-schists, crystalline limestones, or dolomites (generally slightly micaceous), quartz-schists, and schistose or impure quartzites, all having a marked stratified aspect, but distinctly metamorphic. Thus, as it seems to me, stratification is probable in (2), and becomes absolutely certain before the end of (3).

(5) Where rocks of different mineral characters suggest by their association that they were originally stratified, the minor banding of the constituent minerals and the arrangement of platy or acicular minerals is generally parallel with the apparent planes of bedding; that is, there appears to be a connexion between stratification and foliation.

(6) While a foliation may be produced by a pressure in a crystalline massive rock, or in one previously foliated, this, in the latter case, though occasionally the dominant, is generally the subordinate, structure, *i. e.* the *cleavage-foliation* does not, as a rule, obliterate the *stratification-foliation* (see figs. 1, 2, p. 97).

To the age of the metamorphism, and the part to be assigned to pressure, I shall presently return. I will now only notice one point in close connexion with the above conclusions, viz. the indications of unconformity. In a complicated mountain-region such as the Alps we cannot lay much stress upon local changes of strike. Indeed, so far as I have observed, the dominant strike often continues over large areas with remarkable uniformity. Neither must we rely too much upon the absence of a series of beds, and an apparent break in the order of succession, because, as every one knows, extraordinary results may be produced by overthrust-faulting in folding, or by folding of beds previously faulted. At the same time what I have myself seen leads me to suspect that there is very commonly a break between (3) and (4); not perhaps universally, for in the Gothard-Lukmanier region it appears to me difficult to say where the line between the two is to be drawn; but I find it very hard to explain the distribution of (4) in the Central and Western Pennines, as indicated in the maps of the Swiss surveyors and as known to myself, unless we suppose that at least (3) is sometimes even wholly wanting. More than this I will not at present say; but it is quite possible that other unconformities may be hereafter discovered*.

* As there are no names which are yet generally recognized, and the groups themselves are not, and perhaps never can be, very clearly defined, it may render the above description more comprehensible if I exhibit in a tabular form the rocks of this Alpine district in what appears to me their stratigraphical succession, giving for each one or two of its best-defined types, and compare this with the arrangements of other authors. It must be remembered that some groups appear to be rather local, or are missing in certain districts. The first named is the oldest.

		Ex.
1.	(a) Granitoid gneisses	{ Antigorio gneiss (gorge of Gondo) and probably central gneisses of Oberland chain.
2.	(b) Banded gneisses	Simplon Pass, S. side, and Monte Leone.
3.	{ (c) Micaceous gneiss	Lepontine gneisses.
	{ (d) Mica-schists (with garnet &c.)	Tremola schists.
	{ (e) Schists (variable)	Piora schists (below the melanite schist).
4.	(f) Brown-bedded schists	{ The schists above the melanite schist in the Lukmanier region: the Binnenthal-schists.

Other Classifications:—

LORY.		VON HAUER.
Gneiss	{ Granitoid. } = a and b. { Laminated. }	Gneisses = a and b.
Mica-schist	{ Mica-schists, often garnet-bearing, alternating with gneiss. } = c and d.	{ Greenish schistose rock. Saccharoidal limestone. Chloritic and talcose rocks.
Talc-schist	{ Also chloritic and hornblendic, with gneiss-like rock. } = e and f (pt.?).	Recent gneiss } = c, d, e. Mica-schist }
Grey lustrous schists.	{ Also quartzites and gypsums, &c. } = f (pt.?) and later rocks.	Schists (hornblendic, calcareous, &c.) } = f.

Canada.

I proceed next to notice, very briefly, the metamorphic rocks of Canada. Our fellow-workers on the American continent regard the Ottawa group as the base of the Laurentian series. Of this I was not able to examine a typical area, and will therefore merely state that the specimens which I saw were generally coarse granitoid gneisses, resembling, in their absence of definite characteristics, some of the oldest rocks of Britain, and those which appear to be the most ancient in the Alps. The next group, however, to which in certain areas the name of the Grenville group has been given, and to which I believe the majority of the rocks, which I saw in the field, belong, like the second series of the Alps, presents us with a more definite foliation and with indications of stratification. The gneisses commonly vary from moderately coarse-grained to fine-grained; they are frequently "banded," zones distinctly micaceous (or hornblendic) alternating with those mainly quartzo-felspathic, and varying from mere

STERRY HUNT (chiefly after Gastaldi).

Central gneiss=*a* and *b*.

Pietre verdi.

Newer gneiss and schist=*c* and *d*.

Upper lustrous schists=*f* (and probably more than here described).

It must be remembered that these three groupings extend over a much wider area than that to which mine applies. Still a general correspondence will be observed. With one exception, a similar lithological succession may be noted in all. This is the *Pietre verdi* group of Hunt, or the three groups of Von Hauer which I have bracketed as being probably only subordinate members of one group and so its equivalent. The *Pietre verdi* group obviously intervenes between (*b*) and (*c*) of my tabulation. I do not dispute its existence; but in the district of which I have been speaking, it is often wanting and, if ever present, is only imperfectly represented. I have examined specimens of it; but as it is several years since I visited the regions where it is considered to be best developed, I prefer to limit my arrangement as above. I will, however, remark that the group, as at present defined, requires much curtailment. We are told (Hunt, "Geol. History of Serpentine," Trans. R. S. Canada, vol. i. p. 154) that it received its name from "the frequent presence therein of serpentine, diorite, diabase, and related rocks of a greenish colour." It is, however, obvious that, if we use the terms *diorite* and *diabase* in their strict sense, and *serpentine* in that to which most petrologists will now agree with me in restricting it, these rocks, as being of igneous origin, cannot be used in defining a chronological series unless we can prove that they are contemporaneous with it (a point with which Dr. Hunt does not seem to concern himself). Seeing, then, that in all probability many of them (as being coarse-grained rocks) are most probably intrusive, the *Pietre verdi* group may have to be greatly reduced in volume, and may prove to be one rather of local occurrence than of general significance. I may add that this is not the only case where the greatest possible confusion is produced (both in books and maps) by not distinguishing rocks certainly of igneous from those presumably of sedimentary origin. I am well aware that in a district like the Alps this cannot always be done; but in many cases it is perfectly possible, and to lump together these rocks of dissimilar origin fearfully increases the confusion and the difficulties which beset the student. I could name more than one author on the subject of this address whose writings I have occasionally felt inclined to treat as a certain student did his manuscript of Persius, when he threw it to the other side of his room with the exclamation "If you do not desire to be understood, you do not deserve to be read."

lines to layers of considerable thickness. Foliation may be said to be parallel with the apparent bedding, as the minerals are arranged with their longer axes roughly in the plane of the bands, but there is little tendency to split along these. Moreover, the rock in many places exhibits no indication of subsequent crushing. Here and there, however, the mineral layers are considerably corrugated. The following sentence from my Journal sums up the results of a traverse of many miles:—"The same sort of gneiss continues, now darker, now lighter, now coarser, now finer, sometimes almost horizontal, sometimes dipping at high angles." Beds of mica-schist and crystalline limestone occur occasionally, not to mention hornblendic masses of more dubious origin. The evidence of a stratified arrangement in the Grenville group seemed to me very strong in the neighbourhood of Côte St. Pierre. In that district, one of the localities where the problematical *Eozoon canadense* occurs, we have the following succession, apparently in ascending order:—(1) Highly quartzose gneiss (rather coarse)—quartzite of Sir W. Logan; (2) Dark mica-hornblende gneiss; (3) Crystalline limestone with *Eozoon*, containing a thin intercalated band of gneissose rock, and in one place, probably high up, becoming rather distinctly micaceous; (4) well-banded feldspathic gneiss. It is possible that the section may exhibit more variations than this, but I make a very large allowance for repetition by faulting, and omit one or two rock-masses of uncertain origin. I rest no argument on the *Eozoon*, because this structure is at present too much a matter of dispute among geologists to be available in controversy. I will merely say that the crystalline limestone in which it occurs appeared to me to be truly interbedded with the gneiss, and not to be the result of any kind of infiltration. Yet stronger evidence of stratification may be found at Papineauville, where, according to the Canadian geologists, the limestone band of Côte St. Pierre reappears on the other side of a trough. Here we have the following succession, the beds being nearly vertical:—(1) Gneiss, medium-grained; (2) calc-mica-schist; (3) black mica-schist; (4) calc-mica-schists of variable character and coarseness; (5) granite (pegmatite) intrusive; (6) calc-mica-schist; (7) coarse crystalline limestone; (8) calc-mica-schist; (9) quartzose gneiss. Between (1) and (2) there is an interval in which rock is not exposed, and, between (8) and (9), another in which there are only occasional outcrops of calc-mica-schist and crystalline limestone, but the rest are exposed, generally very perfectly, in a shallow cutting opposite to the railway station. The foliation coincides with the apparent bedding, and I could not explain what I saw by anything but some kind of stratification. Microscopic examination fully confirms the above conclusions; moreover, the slides give no indication of a crush-structure, although we might under the circumstances have expected it. From (2) to (8) is approximately 70 or 80 yards*.

* My notes are not quite clear. I had to measure hurriedly, but all these beds are far more than mere layers; for instance, the black mica-schist is quite 16 paces wide, and on the east side passes rapidly into calc-schist, poor in mica.

The Upper Laurentian of Sir W. Logan has often of late years been distinguished by the name of Norian, I have examined this in one district only. The gneisses are peculiar, not the least remarkable being that designated anorthosite-gneiss by Sir W. Logan, which is largely developed. Besides these, there is the great series of gabbros, often containing huge compound crystals of labradorite together with hypersthene. Attempts have been made to claim these rocks, which have an enormous development north of the St. Lawrence, as of stratified origin; but for this I can see no valid reason. These "norites," where I have seen them, are as truly and characteristically igneous rocks, macroscopically and microscopically, as the gabbros of the Cuchullin Hills in Skye, for which a similar origin has been asserted. The one hypothesis has probably no better foundation than the other. Possibly some of the gneisses may be only crushed and recrystallized igneous rocks; but before I speak confidently on this, I must study them more thoroughly than I have yet been able to do. I saw, indeed, a crystalline limestone which may indicate sedimentation, but of this I speak doubtfully, as there was no continuous exposure, and the rock was very full of wollastonite, pyroxene, and garnet. In one place, however, I met with a well-defined quartzite. Considering that some of the rocks most conspicuously associated with this series are of igneous origin, and are possibly not even contemporaneous, that others are dubious, and that the rest (so far as I have seen them) differ varietally rather than specifically from those below, I think it unfortunate that a title founded upon the first-named should have been chosen for the group; and I doubt much whether anything has been gained by departing from the old appellation of Upper Laurentian.

The Huronian series, placed next in order by common agreement, is one of extreme difficulty. I examined a section of considerable extent in the field, and many specimens in museums, besides studying a small collection from Georgian Bay, a typical locality of Sir W. Logan, for which, together with some specimens from the Huronian of Newfoundland, I have to thank Sir W. Dawson. Before my visit to Canada, I could never understand what was meant by the term Huronian; I cannot say I am much wiser since my return. I believe, in short, that the name at present includes rocks in very different stages of mineralization, and belonging to widely separated epochs. The first rock assigned to Huronian which I saw (a short distance west of Wahnapiatae on the C. P. R.), to quote the words of my note, "has a rather flaggy bedding, is much jointed, is rather gritty to the touch, and consists mainly of fine-grained quartz and felspar, having but little mica, though now and then thinnish bands of a fissile mica-schist occur." Its structure and appearance reminded me of the more typical members of the "eastern gneiss" in Glen Docherty (Scotland). This resemblance is confirmed by microscopic examination. It is a fine-grained quartzose gneiss, exhibiting traces of a clastic structure, which, however, is more probably a record of subsequent crushing (followed by cementation) than of original constitution.

*

This is followed, after an interval, by another rock, in aspect more like a schistose dark quartzite, but which, under the microscope, does not materially differ from the last. Nearer Sudbury the rocks resemble dull-coloured quartzites; they contain many fragments, subangular in form, often small, but occasionally as much as two inches in diameter, of a grey granitoid rock. On microscopic examination the matrix seems rather more altered than its macroscopic aspect suggests*, and this also is the case with the quartzites and quartzose fragmented rocks a little beyond Sudbury, amongst which Dr. Selwyn showed me some extraordinary breccias. The matrix of these also exhibits, under the microscope, more mineralization than I should have expected. Between Sudbury and Pagamasing I traversed rocks mainly assigned to the Huronian†, but if I mistake not, the Laurentian series reappears more than once, and there are occasionally bosses of granite and syenite, probably of very ancient date, as they show signs of crushing. In the Huronian series, we passed various quartzites, some very conglomeratic. These, I believe, are considered probably to represent the well-known Huronian quartzite with pebbles of red jasper (which I did not see). There appeared to be slaty rocks, but as two, which, in the field, I thought more probably schistose slates, prove to be fine-grained hornblende-schists modified by subsequent pressure, I do not like to speak with certainty. I obtained, however, a specimen of an indurated volcanic ash and one of a slaty grit, which seems to be nearly in the same mineral condition as those in the Welsh Cambrian series. These Huronian rocks, together with the igneous bosses, appear to have been much more affected by subsequent pressure than the Laurentians south of Wahnapiatae. On the whole, however, I should say that the Huronian series, in the broad belt which runs far inland from North Channel, Lake Huron, contains rocks of more than one age, some of which may prove to be more closely connected with the Laurentian series; but others are distinctly later in age, and in some cases, perhaps, like our English Pebidians, are not very much older than the Cambrian series.

The specimens from the Huronian of Newfoundland are quite of the last-named type. One, which I have examined, is a green flinty slate, which might have come from Charnwood Forest; another is an agglomerate, which, both macroscopically and microscopically, bears a very close resemblance to specimens which I have described from Tairffynnon and other localities near Bangor.

Within the last few weeks, through the kindness of Prof. Boyd Dawkins, I have had the opportunity of examining a small collection of rocks and slides, illustrating the junction of the Laurentian and Huronian, from the Lake of the Woods, Manitoba. I should not

* Small crystals, apparently endogenous, of a brown mica are abundant. The microscopic structure of the rock presents a resemblance to that of the Ober-Mittweide conglomerate, described by Dr. Lehmann. For the opportunity of examining the latter I am indebted to Mr. J. J. H. Teall.

† To this belt of Huronians (in which, as said above, some Laurentians and igneous masses are included) a breadth of about 100 miles is assigned.

have hesitated to refer all these to the former series, and cannot say from the specimens where the line of division comes, although one of the so-called Huronians is less coarsely crystalline than the admittedly Laurentian. The difference, however, is not greater than might be readily explained by a bringing together by faulting of rocks originally some distance apart in the same series; and, as all the specimens give indications of a very ancient crushing, it is quite possible that this may account for the apparent diversity, which is after all hardly greater than we may observe in some cases of consecutive masses near Gairloch. I may add that, when at Winnipeg, I saw in the Museum some specimens of the Huronian and Laurentian from the same region, and did not see how the former were to be separated from the latter.

A collection of slides also of Huronian rocks from the south of Lake Superior, selected by Dr. A. Wichmann, has been lent to me by Prof. Judd. Several of these remind me of specimens which I obtained to the east of that lake. Some are distinctly of elastic origin, containing small fragments of Laurentian gneisses, but with considerable alteration in the matrix; others have a general resemblance to members of the uppermost group of Alpine schists, while others, again, seem hardly more altered than a Cambrian slate, when it has been subjected to rather exceptional pressure. Some of the slides are obviously from rocks of igneous origin, and so cannot be taken into consideration. The first named of these specimens indicate that the break between these and the Laurentians must be considerable.

When in Canada, I saw specimens of the red felstones correlated by Dr. Sterry Hunt with the Arvonian of Dr. Hicks. They undoubtedly bear, macroscopically, a close lithological resemblance to the devitrified rhyolites of the Bangor-Carnarvon district.

I was not able to visit any exposure of rocks placed in the Montalban group. The specimens shown to me by Dr. Sterry Hunt bore a remarkable resemblance to members of the Tremola schists and the underlying gneisses of the Lepontine Alps. I did not visit any area occupied by the rocks called Taconic, and so have not been able to form any opinion as to the value of the group.

With regard to the stratigraphical sequence of these groups, it would be presumptuous in me to express a very decided opinion. But I will venture to say that, if the red felstone (petrosilex) group underlies the Montalban series (except by intrusion), it will be the most startling and inexplicable fact that has come to my knowledge since I began to work at this branch of petrology; and that while it is very probable that some of the rocks now assigned to the Huronian may immediately follow the Laurentian or in some cases be a part of it, others, I think, must be decidedly later than the Montalban; if not, the teaching of nature in the New World contradicts the lessons which she gives us in the Old World.

Cornwall and South Devon.

As I have already described, in the pages of our 'Journal,' the

metamorphic schists of the Lizard district, a very brief recapitulation of my conclusions will suffice. The series can be subdivided into three groups, to which I have given, for purposes of reference, the epithets micaceous, hornblendic, and granulitic. In the first and lowest, consisting mainly of chloritic, hornblendic, and mica-schists, distinctly green schists predominate; in the second, which vary from well-banded schists to almost uniform and rather massive rocks, black hornblende is the most conspicuous mineral; the third is characterized by the presence of a quartz-felspar gneiss, with but little mica or hornblende, interbanded with more micaceous or hornblendic layers. The dip is not usually high, more commonly below than above 45° , and the dominant orientation of the minerals is with the apparent bedding-planes. In the lowest series bedding is indicated by distinct mineral changes visible to the eye in the field and fully confirmed by microscopic examination. In the upper series there is just the same rapid alternation of bands widely differing in mineral character that I have described in the melanite-schist series of Val Piora. Hence if we were to give up the false bedding which I have described in the middle group (though, after careful reconsideration, I feel it very difficult to explain this as the result of mechanical movements), and were to assume the whole group to be a mass of crushed dolerites affected by mineral changes (which a part may very well be), still there is, above and below this, evidence of stratification. Further, even if we reduce the apparent bedding throughout to gliding planes, and suppose the whole series to be some extraordinary complication of mashed-up igneous and sedimentary rocks (which I regard as most improbable), there can, even then, be no question that this rolling out, this metamorphism of the most exaggerated kind, is anterior to the intrusion of the peridotite (now serpentine), the gabbro, and the granite, from which all signs of crushing (save some local disturbance near a fault) are absent. Yet more, in the conglomerates of Nare Point, now thought to be of Ordovician age, hornblende-schist, like that of the neighbouring crystalline *massif*, is found together with a granitoid gneiss; and little bits of micaceous schist abound in the conglomerates of the Meneage district, together with fragments of hypometamorphic rock. Thus the schist series of the Lizard must be vastly older than the supposed Ordovician rocks against which it is faulted, and so, in accordance with the ordinary laws of reasoning, may be classed as Archæan.

I may pass yet more briefly over the South-Devon rocks. In the associations of the mica-schist and chloritic schist which I have described we have indubitable evidence of bedding, and to this the earlier foliation has a general parallelism. But a secondary structure, a cleavage-foliation, has been in many cases impressed upon the rock-masses, and this, as I have pointed out, is due to the same set of earth-movements as have produced the foldings and cleavages of the adjacent Palæozoic strata, and these, in some cases, have given rise to very remarkable structures. The schists and the Palæozoic series are brought together by a fault. They evidently differ widely in age; but as the latter are probably rather newer than the Cornish

strata mentioned above, the evidence for the Archæan age of the former at present before us is not so strong as in the Lizard district.

North Wales.

It is, I think I may assume, needless to occupy your time with proving that the devitrified rhyolites in the Bangor-Caernarvon district are not Lower Cambrian rocks metamorphosed *in situ*. That hypothesis may be regarded now as having no more ground than the Ptolemaic system in Astronomy. If the microscope is not useless in Geology, we may take it as proved that below a certain well-marked conglomerate forming the base of the Cambrian there come slaty rocks, grits, and conglomerates or agglomerates of volcanic materials, the exact thickness and the details of this second series being immaterial for my main purpose. Further, it will be now generally admitted that a conglomerate representing either the first-named or one of the latter (which it now matters not) rests in some places on a coarse granitoid rock and is almost wholly made up of its materials. There is also considerable (to my mind convincing) evidence that the rhyolites are much newer than the granitoid rock. Hence whatever be the genetic origin of the last, whether it be a true gneiss or whether its gneissoid character (for it is no normal granite) be due to subsequent pressure, it is vastly older than the Cambrian, and therefore represents some portion of the Archæan series. If we may venture to argue from lithological similarity, this should represent the gneissic series of Tycroes in Anglesey, which is certainly older than the great mass of the schists of that island; and these, as I have said, are much anterior to the rhyolitic conglomerate, which cannot be newer than the basement-bed of the Cambrian.

The stratigraphy of the island of Anglesey is at present in such confusion, and my own work among it has been of so fragmentary a character, that, in accordance with my present plan, I shall pass very briefly over the evidence which it affords bearing on the question of the relation of foliation to stratification and cleavage. But, after the papers of Dr. Hicks and Dr. Callaway, we may, I think, safely admit that the gneisses and crystalline schists of that island are much older than even the earliest part of the Cambrian period as usually defined. What I have myself seen leads me to regard the coarse granitoid gneisses (and I think this will generally be admitted), such as those exposed near Tycroes and Llanfaelog, as the most ancient rocks; these, if we can trust lithological similarity, should be correlated with the older part of the Hebridean series of Scotland. The very abundant, fine-grained, rather fissile, micaceous and chloritic schists I regard as later in age, but still as much older than the Cambrian. There is no valid reason that I can discover for correlating these with the typical Pebidian group of St. Davids, or with the group on the opposite mainland which underlies the basement conglomerate of the Cambrian series. If there is anything in comparative lithology, the last two are decidedly younger than the schists, and are probably the equivalents of the hypometamorphic series in Anglesey described by Dr. Callaway. These schists have undoubtedly been much

modified by subsequent pressure, which, however, I strongly suspect operated before the basement-Cambrian conglomerates were formed, and this pressure acted, in some cases at least, on rocks already foliated. Further, the occasional interbedding of quartzites with these schists is a proof of sedimentation, and in these cases (to speak of no others) the foliation agrees with the bedding.

Other Districts in England and Wales.

Over the remaining districts in England and Wales I must pass briefly. As regards the St. Davids district, I have nothing to add to the remarks which I made last year; but, through the kindness of Mr. Allport, I have had the opportunity within the last few weeks of examining a fine series of slides and specimens representing parts of the Malvern range. Of these I trust that before long he will send us a notice; but I may say that the coarse-grained rocks from the northern hills exhibit the effects of compression, to which, as in the case of the granitoid gneisses of Wales, their present gneissic structure may in some cases be due. At the southern end of the range, however, rocks more distinctly foliated and non-igneous in origin are found, together with true mica-schist. The granitoid gneisses on the flanks of the Wrekin present considerable resemblances to rocks which I have obtained from masses elsewhere of admittedly "Laurentian" or Hebridean age, though their structure has in places been much modified by subsequent crushing. There can be no doubt, I think, that Dr. Callaway is fully justified in including them in the same general group as the rocks of the Malvern Hills. The rhyolitic rocks of the Wrekin district and of other areas, in short the various masses of slates, agglomerates, and old rhyolites, which, though older than the Cambrian group, cannot be very widely separated from it, hardly fall within the scope of my present subject.

Scotland.

In the summer of 1879 I examined the rocks around the upper part of Loch Maree, and communicated to the Society the results of my work. Since then I have had opportunities of examining considerable collections from this and other districts of Scotland, and in the autumn of last year spent some time in the former district and at Gairloch. The rocks of this last region have an exceptional importance because their Hebridean age is universally admitted, and their distinctive characters and probably higher position in the series have been pointed out by more than one observer. In my description I shall suppress microscopic details, but I may remark, once for all, that I have verified every point of importance by the examination of slides cut from specimens collected by myself. Commencing with the elevated moorland between Gairloch and Pollewe, we find abundantly on the eastern side of the watershed moderately fine-grained, very distinctly banded gneisses. Quartzo-felspathic and more micaceous * layers alternate, varying in thickness from 2 or 3

* The mineral is commonly a black mica, but hornblende also occurs.

inches downwards. A rather fissile structure may be noted parallel with the banding, and the strike is roughly N.W., with a high dip (about 70°) on the eastern side. The resemblance of some of the less fissile varieties to the moderately fine-grained Laurentian gneisses of Canada is most remarkable. Gneisses of a similar character, but, perhaps, slightly finer grained and with a rather compressed aspect, continue for some distance on the Gairloch side of the watershed, the strike becoming rather N.N.W. These appear to change gradually to a dark green, fine-grained, and rather fissile hornblende-schist; and this is the general character of the rock seen by the roadside until we approach the straggling village of Gairloch, except that in one place I noted a fine-grained, dark mica-schist. About the new hotel at Gairloch and on the shore we find Torridon sandstone. The lowest part of this is a breccia crowded with fragments of crystalline rock, angular and subangular, the most abundant being a hornblende-schist, practically identical with some of those just mentioned, and a very fissile and fine-grained mica-schist, though fragments of the gneisses are not wanting. On the shore below the Free Kirk both these schists may be seen *in situ* beneath the breccia. Proceeding towards the bay, near the old burial-ground, we pass fine-grained mica-schists with occasional garnets, and then come, on the northern side, to a rather fine-grained micaceous gneiss, followed by a dark green schist, and that by a fine-grained gneiss. These rocks have a rather fissile structure, and the strike of it and the foliation is between N.N.W. and N.W., with a high dip on the western side. At a headland on the opposite side of the bay we find, first, a fairly fine-grained micaceous gneiss passing into one slightly darker and more hornblende, followed by a very dark green, almost black, hornblende-schist, and that by a variable darkish gneiss of slightly porphyritic aspect, beyond which comes a rather coarser, more felspathic gneiss. All these rocks are somewhat fissile, especially the last named, and this structure, which coincides with the foliation, agrees with that at the last-named headland, striking about N.W., with a high dip to S.W. Similar variability in mineral character may be seen, and a similar structure noted, at other places in this neighbourhood. On the road from Gairloch towards Talladale we pass various rather fine-grained, dark, micaceous gneisses, or, perhaps, occasionally strong mica-schists, the usual strike being about N.W. and the foliation nearly vertical. Approaching the Kerry Falls, we find variable fine-grained gneisses followed by less fissile dark mica-gneiss, and that by a rather greener compact schist; and on the upland just above the Falls we find first a very fine-grained mica-gneiss, followed by a similar mica-schist, and that by a fine-grained hornblende-schist. The rocks about here exhibit a marked flaggy structure like bedding. This has a N.W. strike, is nearly vertical, and it is parallel with the microscopic foliation.

An examination of this district leads, I think, to three conclusions:—(1) that the mineral changes in the rock are indicative of some kind of stratification; (2) that if the fissility (which is sometimes very marked) and the foliation be due to pressure, this has

acted roughly at right angles to the planes of original stratification ; (3) that when the basement-breccia of the Torridon Sandstone was formed, these rocks had arrived substantially at their present mineral and structural condition.

Proceeding now to the upper end of Loch Maree, I shall facilitate my description by referring to my paper read in 1880. In this I contended that the so-called Logan Rock was not an intrusive mass, but a portion of the Hebridean gneissic series brought up by faults. I also maintained that the alleged unconformity in Glen Docherty between the older and newer gneisses did not exist, and that the latter series, though exhibiting in places a fragmental structure, was rightly called metamorphic. All this my recent examination has confirmed. But in one theoretical conclusion I went completely astray. As the evidence for separating the "newer gneiss" between Glen Logan and Glen Docherty had broken down, and as the fragmental structure which I observed in it seemed to disappear as the rocks were followed southward, I concluded that Sir Roderick Murchison was right in maintaining a progressive metamorphism in this direction. At that time, however, I thought that possibly the whole series might turn out to be Archæan ; but this solution of the difficulty was soon demonstrated to be impossible, and further study of specimens from this and other districts, viewed in the light of my alpine work of 1883, caused me to suspect what would be the explanation of the puzzle *, namely, that the fragmental structure was not a record of original deposition, but of a subsequent crushing *in situ* of crystalline rocks. In the hope of clearing up this point, I worked (last autumn) up the eastern arm of Glen Logan to the back of Ben Fyn, and on another day, from near the little gorge where the stream cuts through the so-called syenite, I ascended the cliffs to the upper moorland and summit of Craig Roy, whence I descended to the high-road in Glen Docherty, near the seventh milestone from Achnasheen. I thus examined as continuous a series of outcrops of the "newer gneiss" as was possible, and collected a number of specimens which I have since studied with the microscope. I have now no doubt that here, as in the districts further north, the apparently bedded structure cannot be relied upon as the result of original deposition, but is to a great extent, if not wholly, a record of the effects of earth-movements upon rocks originally crystalline. These have been crushed and, as it were, rolled out, as the whole mass has been thrust forward and upwards over the broken surfaces both of older crystalline and newer sedimentary rocks, which once formed parts of a great and perhaps complicated overfold. At the same time,

* When I wrote the lithological notes to Dr. Hicks's and Dr. Callaway's papers on N. W. Scotland in the winter of 1882-3, I was still, as may be seen, in a fog about the significance of the fragmental structure in this peculiar "upper" or "slabby" gneiss, though I was becoming almost daily more impressed with the importance of the effects of subsequent crushing. If, for the group numbered I., and there supposed to be the newest chronologically of the three, as retaining traces of an original clastic structure, we read "No. II. or III. crushed *in situ*," all will be clear.

as we pass over the outcropping edges of the apparent strata, marked mineral differences, both macroscopic and microscopic, can be noted, which seem to indicate a true succession in the beds, which have thus been modified by subsequent pressure, and I am inclined to think that the general strike of the two structures is the same. The greatest crushing, the greatest shearing—in short, the greatest modification—of the original constituents is at the northern escarpment of the overthrust mass. On the summit of Craig Roy and in the upper part of Glen Docherty, these effects, though still marked, are generally less extreme. It is, I think, possible to infer the original character of the rocks from which this part of the “newer gneiss” has been formed, viz. that they were rather fine-grained gneisses, not very unlike those of Gairloch, occasionally highly micaceous, but usually quartzose. I am certain that in none of the sections that I examined was there any representative of the quartzite series. It would no doubt be more difficult to distinguish an included and compressed fold of the Torridon Sandstone, but I believe that I may with equal confidence deny its presence. So far as I can judge from a more superficial examination, this series of quartzose and micaceous rather than felspathic gneisses extends for some miles southward and reappears in other parts of Scotland, as do rocks undistinguishable from the somewhat more coarse-grained varieties near Gairloch.

Before leaving this subject, I may mention that we find a close parallel to the “newer gneiss” series of the northern escarpment on the southern edge of the crystalline *massif* of the Central Highlands. In the cliffs north of Stonehaven the Old Red Sandstone is underlain* by an apparently bedded series exhibiting similar fragmental characters, and similar indications of partial metamorphism to those which we observe in the northern cliffs of Craig Roy; and as we follow the shore northward the clastic character becomes less, the metamorphic more marked, until at last we cannot doubt that we are examining a series of fine-grained gneisses, although they still exhibit some signs of subsequent crushing. This at Muchalls (some three miles further north) is still less conspicuous, being sometimes distinctly subordinate to the original foliation, to which it is often inclined at a high angle. But, near Stonehaven the fissile structure is occasionally so marked that the rock splits up like a slate. Other masses, again, might readily be taken for compressed quartz-felspar grits, like the Torridon Sandstone; but careful work on the ground after microscopic examination of specimens clears up the difficulties. The dip of the apparent bedding is generally about N.N.W., and is usually pretty high, sometimes as much as 70° . Here also these structures have a general correspondence with some marked mineral changes in the rocks, and look as if, at any rate, the strikes of the subsequent cleavage and the original bedding coincided.

Microscopic Structure of the Older Archæan Rocks.

Not the least difficulty in the investigation of the most ancient

* The junction is a faulted one.

gneisses and schists is that of securing typical specimens. In the search for these we are necessarily limited to districts where the pre-Palæozoic age of the rocks can be proved by their position beneath, and marked discordancy from, some part of the Cambrian or very lowest Ordovician series, or at least by their forming part of a series which can be somewhere seen in this position. But even in these districts the great age of the rocks renders them liable to subsequent alteration either by the percolation of water, or by crushing followed more or less by mineral reconstruction. Thus regions which have been the scene of mountain-making are unfavourable to our quest. Hence our own country does not provide us with good types, although its rocks may become useful at a later stage of our investigations. Those which I have studied with most advantage are from the Laurentian series of Canada, the antiquity of which is beyond dispute, and from districts which appear to have been singularly free from any marked disturbance since an epoch long anterior, at any rate, to that when the basal materials of the Potsdam Sandstone were deposited. The macroscopic aspect of these rocks has been already described. I will endeavour to indicate their more characteristic microscopic structures, although it is most difficult to describe them in words, without the aid of large coloured figures.

The gneisses in the Laurentian series—for to these, as the dominant rocks, I will restrict myself—mineralogically do not differ materially from granites: quartz, felspar (often potash), and black mica or hornblende are the principal minerals; white-mica, garnet, apatite, sphene, magnetite, or some iron-oxide, are rarer and more accidental constituents. They are holocrystalline, presenting many resemblances macroscopically to granites of moderate coarseness, but distinguished by a tendency to mineral banding, as above described, which is sometimes very definite. If we examine slices cut perpendicular to the banding, we note that the sections of the mica lie with their longer axes roughly parallel with it. The same remark applies also to any mineral of elongated form; and minerals of the same species exhibit some tendency to be associated in these layers. Any such grouping is extremely rare in a granite, and the circumstances under which it occurs suggest an explanation. The two rocks, however, agree in that the mica-crystals are well developed, and of a fair thickness compared with their basal area—*i. e.* are not mere flakes. Again, in a moderately coarse granite (I expressly exclude the very fine-grained granites, which usually occur in veins and small bosses, the rock called *granulite* by some authors), the crystals of felspar, where in contact with quartz, exhibit, as a rule, a rectilinear boundary; but in these gneisses, while the boundary between the two minerals is clear and definite, it is curvilinear, the grains of both being either rounded or even somewhat lobate in outline, as if the two minerals had simultaneously but slowly segregated out of a viscid mass. Thus, according to the predominance of either mineral, rounded grains of quartz may be seen included in larger grains of felspar or *vice versâ*. The struc-

ture, in short, of the rock recalls to mind that of some of the more highly altered quartzites, and is sometimes slightly shadowed out by such fragmental rocks as the Torridon Sandstone, although I do not therefore mean to assert a clastic origin. Occasionally the peculiar association of quartz and felspar, which might be designated microdendritic, is to be seen; I may also remark, without wishing to attach too much value to the fact, that in these gneisses microcline felspar is remarkably abundant. The hornblende rocks, presumably interstratified with these gneisses, are also coarsely crystalline; indeed this is the general characteristic of the series, whether its members be quartzose, felspathic, micaceous, calcareous, or otherwise. Even the crystalline limestones have a character of their own, both in their crystalline structure and in the not unfrequent presence of various accessory minerals, such as garnet, malacolite, or other members of the pyroxenic group, mica, &c.

As the gneisses become more finely grained, the structure described above is less marked, and the grains of quartz and felspar assume a rather more irregular outline, analogous in some respects to that to be seen among certain of the vein-granites, so that occasionally it is by no means easy, in the hand specimen or under the microscope, to distinguish one of these gneisses, when almost without mica or signs of foliation, from certain of the vein-granites. But, as a rule, in this series, mica is more abundant than in the last, the rocks vary more frequently, and the different members are less coarsely crystalline. This diminution in the felspathic constituent seems to become more marked as we proceed upwards; and where this mineral does appear in rocks presumably of stratified origin*, it has generally an ill-defined outline, an uncharacteristic aspect, and is commonly ill preserved. The aluminous subsilicates now become more frequent, appearing to take its place; mica is a very common mineral, so that mica-schists are often very abundant. White mica now seems rather commoner than black; the accessory minerals, such as garnet, andalusite, cyanite, &c., are often well developed; but the matrix is, as a rule, not coarsely crystalline. As we proceed onwards, it can no longer be doubted that we meet with signs of original stratification, and with rocks which must be of detrital origin. Well-crystallized accessory minerals (especially silicates) seem to become rarer; the matrix not only is apt to be rather minutely crystalline, but also sometimes seems to contain a residuum of uncrystallized material, carbonaceous and earthy particles occasionally remaining and giving a dirty aspect to the crystalline constituents of the rock. So far as I have observed, and this seems to me very important, these rocks exhibit stratification-foliation, that is, the general direction of the constituent folia is parallel with the apparent stratification of the rock-masses. This, as it affects such large areas, appears to indicate that the dominant pressure at the time of crystallization was vertical rather than lateral. Hence, either the rocks were buried deep beneath other

* As in the gneisses so common in the Lepontine Alps, the "Montalban" type of Dr. Sterry Hunt.

strata, or the atmospheric pressure was much greater. I may remark also that where some of the earlier Archæans have been considerably folded, and these plications are obviously anterior to Cambrian times, the rocks appear to have bent more readily than they afterwards did. This is what we might expect. In very early ages of the earth's history, the rapid escape of heat would cause frequent bending of the crust; but the temperature would increase quickly downwards from the surface, rendering the rocks, as a whole, more plastic*.

Pressure Metamorphism.

The aforesaid changes will be best understood after describing the effects of pressure followed by more or less mineral change upon different kinds of rock. Let us take first the production of slaty rocks from comparatively homogeneous shales. This subject has been so admirably treated by my predecessor in this chair, Dr. Sorby, that I need do little more than make a passing reference to it, and will merely state that my own investigations fully confirm his statements concerning the presence, in many slates, of exceedingly minute flakes of a micaceous mineral in large quantities. These I think to be most probably, in the main, of secondary origin. Perhaps the reason of their production may be that in these cases the felspathic minerals, whose detritus was the principal constituent of the slate, had not been so fully deprived of their alkalis as in those where kaolin is chiefly present. Still, exogenous mica may be often observed. The crystallization of the above-mentioned minute mica-flakes is, no doubt, *ceteris paribus*, a consequence of the pressure to which the rock has been exposed. They are most conspicuous and best developed in regions which have obviously undergone great folding and compressing, and in these they can sometimes be seen to be most markedly developed where the pressure has been most intense. Hence these glossy slates or phyllites may be regarded as a first step towards the formation of a mica-schist. But it must be remembered that it is a first step only, and between it and a normal mica-schist there is a very wide interval, in which intermediate forms but rarely appear. Such forms also, when they do occur, are found, not in any part of the series of well-marked crystalline schists, but only (so far as I know) among those to which from other considerations we should assign a comparatively late date. Some remarkable instances of these *phyllites* have been shown to me by Professor Boyd Dawkins from certain localities in the Skiddaw Slate of the Isle of Man. From specimens which I have seen I infer that

* From the above remarks, and others in this address, I may be supposed to favour the idea of a community of structure in rocks of dissimilar origin. I therefore think it well to say that my work has led me to the exactly opposite conclusion, viz. that rocks of dissimilar origin have dissimilar structures. Of the alleged identities, some are mere superficial similarities, very much of the "Monmouth and Macedon" type; others are due to the structure being too minute to be properly appreciated and distinguished; others, again, occur, as among the oldest rocks, where we are ignorant of their origin. I only hold that an original structure can be subsequently obliterated.

similar instances exist in Scotland, among the slaty rocks to the south of the zone of the crystalline schists of the Central Highlands.

Subsequent work on the part of several investigators has thrown additional light upon the second kind of cleavage mentioned by Dr. Sorby in his Address, that in which the cleavage-planes cut across the undulating bands of the constituent minerals. Of this structure I possess one or two excellent examples, *e.g.* from near Torcross, which makes it clear that the structure is an example of the strain-slip cleavage (Ausweichungs-Clivage) of Dr. Heim*. These planes of weakness, both in this and in ordinary cleavage, as noticed by Dr. Sorby, are marked out by secondary mineral deposits. It is needless to enter into a minute description of the effects of pressure upon less homogeneous fragmental rocks, since, so far as they bear on my present subject, I shall have to refer to them in speaking of the crystalline rocks.

The effects of pressure upon these last are only beginning to be fully realized. It has long been known that pressure or strain, definite in direction, acting during the solidification of the rock, modifies the position of its constituents; but it is only lately that the effects of these on rocks already crystalline have been apprehended. Let us take as an example the effect of pressure on a holocrystalline rock such as the granitoid gneiss already mentioned as forming the central part of the Bernese Oberland. Excellent examples may be found in the gorge of the Reuss or near the Furka road, in the neighbourhood of the Rhone glacier. We can there trace a gradual sequence from the coarse granitoid gneiss to very fine-grained slabby bands, the surfaces of which are coated with extremely minute scales of silvery mica. The original constituents of the rock are mainly quartz, more than one kind of felspar, and biotite. If we examine under the microscope a specimen taken from a part where the effect of crushing is beginning to be conspicuous, we find that the felspars are cracked or broken across; the fragments are displaced from their original position, they seem to tail off into a mass of microliths of a white mica, evidently formed from the finer detritus, bordering the larger grains, crowding cracks in them, sometimes interspersed throughout their whole mass, until it has almost lost its distinctive characteristics. The larger grains of quartz are also cracked and broken, and with polarized light exhibit the usual strain-phenomena. Much secondary quartz of chalcédonic aspect has formed in little streaks and elongated pockets. The biotite seems to have been pushed about, has often a "tattered" look, and sometimes seems to have recrystallized; a wavy, lenticular cleavage-structure at right angles to the direction of pressure has become conspicuous, showing sheen-surfaces to the naked eye. As we examine specimens further away from the uncrushed rocks, we find the felspar gradually disappear, all the constituents of the rock become more and more minute, and thus it assumes a more homogeneous character; everything seems to have broken up, and it bears some resemblance to one of the phyllites described above, or to

* Mechanismus der Gebirgsbildung, Taf. xv. fig. 11.

an exceedingly fine-grained, foliated, micaceous quartzite; until at last, according to circumstances, our gneiss is converted into a very fine-grained, slightly foliated mixture of quartz, micaceous minerals, and earthy or ferruginous materials, which might readily be taken for an impure quartzite or quartz-schist, or else into one of the above "sheeny" fine-grained micaceous schists. We have here, as may be found in many other localities, an almost complete transitional series; but it is of course open to question, as I have already said, whether the rock was originally a true granite or not, though in any case its foliation cannot have been more marked than in some of the Laurentian gneisses described above. There are, however, in other districts, cases where the first stages of these changes, viz. the production of a certain amount of foliation in a true granite, may be observed, and these are similar to the earlier stages described above, though often not carried quite so far, so that it is needless to dwell upon them in detail. Suffice it to say that the felspar crystals lose their angular outline, and become more or less rounded, doubtless by a crushing away of the angles. The original micaceous constituents appear to undergo some amount of rearrangement at right angles to the pressure, a rude wavy cleavage becomes perceptible in the same direction, and becomes coated by the usual filmy white mica, which also, as before, is developed throughout the rock. Hence I have no doubt that many of the augen-gneisses, where the "eyes" are rounded crystals of felspar, are only porphyritic granites modified by subsequent compression.

When a rock which originally possesses a well-marked banding or foliation, is exposed to pressure, much more varied results will be produced. I have already described* how in the case of a fine-grained banded sedimentary rock the mineral banding appears to be intensified by a pressure acting at right angles to it, while it may be bent and ultimately undergo strain-slip cleavage by one acting at a high angle, or else (I think, if the pressure acts at a smaller angle) may be in places obliterated and converted into a kind of lenticular structure, recalling certain gneisses, in which, though there is a foliated structure, there is no marked mineral banding. Gneisses and schists undergo somewhat similar modifications, which can be fully studied in the Alps, in Scotland, and in many other mountain-regions, past and present. In the first-named two I have given reasons for considering that the primary foliation of the rocks, where distinguishable, corresponds with bedding. If we examine some of the Alpine schists or gneisses where mineral banding is conspicuous, we shall find that the pressure due to the earth-movements has acted upon these in different directions, and with varying intensity. Sometimes there will be little sign of disturbance, sometimes the pressure has been perpendicular to the stratification-foliation, and gives to the layers a flattened or rolled-out look †. Sometimes these are bent and zigzagged, and folded in the most com-

* "On the Geology of the South Devon Coast," Q. J. G. S. vol. xl. p. 18.

† Indeed they sometimes suggest the action of lateral tension rather than of vertical pressure, an action possible, locally, in a folded region.

plicated manner; sometimes strain-slip cleavage, or, as a variety of this, overfold strain-cleavage, is produced. The constituent minerals exhibit to a greater or less degree indications of fracture and disturbance, obviously very much depending on the form and nature of the mineral; but, perhaps owing to the absence of felspar, there is not quite so much of crushing and of mineral change as in the rocks described above. Still, mineral deposit takes place along the planes of cleavage, sheen-surfaces are formed, and these may be traced in every degree from the stage where they are quite subordinate to the stratification-foliation, to that in which the latter has been wholly obliterated by cleavage-foliation, when the rock splits up into thin slabs, sometimes almost films, of a friable micaceous schist, which we might almost call a slate (figs. 1 & 2).

Fig. 1.



Fig. 2.



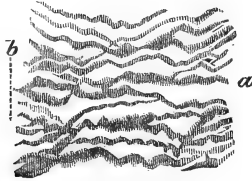
Fig. 1.—Fragment of Lepontine Gneiss (about $3\frac{1}{2}$ inches long) showing stratification-foliation—darker bands (*a*) chiefly biotite; lighter, chiefly quartz, with some felspar;—the cleavage-foliation, indicated by filmy white mica, parallel with line (*b*) and perpendicular to the paper. The flakes of dark mica exhibit a certain parallelism to the plane through (*b*). Near Altanca, north side of Val Bedretto.

Fig. 2.—Fragment of Calc-mica Schist (about 3 inches long) showing stratification-foliation affected by cleavage-foliation. (*a*) Bands of greenish mica, (*b*) the direction of the cleavage-foliation, indicated on the faces of the specimen (not seen) by platy surfaces, spotted with filmy white mica; the flakes of mica in (*a*) tend to be parallel with the plane through (*b*). From above the Tremola schists, north side of Lago di Ritom, Val Piora.

Very interesting changes of a like nature will be found on the Aberdeenshire coast, north of Stonehaven. At Muchalls, the rock which forms the crags is commonly a very fine-grained quartzose gneiss, the mica layers (chiefly biotite) being from $\cdot 1$ to $\cdot 2$ of an inch apart. These are greatly zigzagged and corrugated; in some places the surface of a block is seen to be traversed by bent and

wavy lines, which at intervals are crossed by roughly parallel, thicker, dark bands, so as to present a good imitation of false-bedding; but the latter are quite absent from some parts of the block (fig. 4). On close examination of specimens, we find every transition from the simpler to the more complicated structure. These broader bands are either records of the strain-slip cleavage or of that strained compression of layers (which may eventuate in cleavage) formed in a series of overfolds. As an extreme case, these darker, or secondary layers, as we may call them, dominate over others. The rock, then,

Fig. 3.

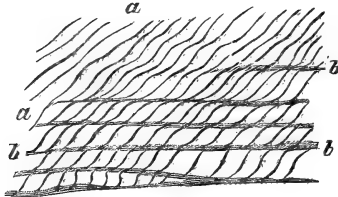


Quartzose gneiss (chiefly quartz and biotite). Stratification-foliation (*a*) modified by pressure approximately at right angles to it. The mica-flakes in the bands (*a*) are mostly parallel with line *b*. About natural size. From the cliffs at Muchalls (Aberdeenshire).

when acted upon by the weather, tends to split along them, and the surfaces are seen to exhibit the characteristic sheen already mentioned. The most perfect examples of this can be seen on the rocky shore, a short distance south of Muchalls, close to a target.

On examining specimens of these rocks microscopically, we find that one of those in which a wavy banding only is exhibited, chiefly differs from an ordinary rather minutely granular quartzose gneiss in a general parallelism of the flakes of dark mica to a plane roughly at right angles to the average direction of the planes of foliation (fig. 3),

Fig. 4.



Quartzose gneiss (as in fig. 3). Part of a block, showing the original stratification-foliation (*a*) modified by pressure and producing a cleavage-foliation (*b*) by strain and rupture of flexures in part of the specimen, thus mimicking false-bedding. The drawing is diagrammatic, about $\frac{1}{3}$ natural size. From a fallen block smoothed by waves just south of Muchalls.

Throughout the rock also the constituents, if irregular in form, seem to have a similar orientation. The rock, in its present condition, does not exhibit marked indications of crushing. When we examine specimens of the apparently false-bedded rock, we find that the quartz and the felspathic granules have a more fragmental

look, although evidently, in the case of the former, much recrystallization, *in situ*, has taken place, so that the rock, at first sight, has quite the appearance of a normal crystalline schist. A white mica is here fairly abundant. The mica flakes are very often parallel with the directions of the thicker bands; but even in these the rule is by no means universal, while the thinner layers sometimes exhibit much irregularity, a majority of the flakes occasionally pointing in the direction of the layer. This is also true of the most cleavable specimens, in which, even in the thicker bands, the dominant tendency of the mica flakes is rather in the general direction of the thinner bands, viz. at a considerable angle with the former.

These structures, as it appears to me, can only be explained as follows:—The rock must have been already a crystalline foliated rock before it was exposed to the pressure to which the present modifications of structure are due. When this acted, it must have been in a condition (probably of slight plasticity) which allowed of a certain amount of movement of its constituents without serious rupture of continuity*. Thus the folia were bent, and the mica flakes, probably with some amount of recrystallization, were enabled to arrange themselves at right angles to the pressure (fig. 4). In the other cases, whether from slight differences in the constitution of the rock, or from local circumstances causing it to yield more readily, there was more disturbance of the constituents, the mica layers were more distorted, and in some cases were pressed or drawn together (fig. 3). Here also a certain amount of recrystallization, how much it is difficult to say, has taken place†.

It will be noticed that my explanation of these structures does not quite agree with that given by my distinguished predecessor Dr. Sorby. It is with the utmost diffidence that I differ even in the slightest degree from so careful an observer and so acute a reasoner, but I have been unable to come to any other conclusion. He regards, if I understand him rightly, the cleavage-foliation as the result of the metamorphism of a cleaved detrital rock, while I regard it as a structure superinduced upon a rock which was already possessed of stratification-foliation.

Further to the south, in the cliffs a little north of Stonehaven, the cleavage-foliation has practically obliterated the stratification-foliation. The rock also, as already said, has a much more marked fragmental character, so that many specimens might be readily mistaken for slightly metamorphosed clastic rocks. Here and there, however, I can detect remnants of the old lines of foliation, which by their pressing or dragging together have formed the now dominant bandings of mica which make the cleavage-foliation. It is interesting to note that in these rocks the mica flakes are generally much less perfectly defined than in those described at Muchalls, the mineral being, what I may call, confusedly crystallized. It is almost impossible to say precisely what is the origin of some of

* The possibility of this is indicated by the well-known experiments of Tresca and others on the "flow of solids."

† I may remark that not seldom a mica, practically colourless in thin sections, seems to form from biotite by the extrusion of the iron-oxide.

these rocks just north of Stonehaven; the most gritlike may possibly be a crushed-up granite, but some of them, I feel sure, have been fine-grained quartzose gneisses very similar to those at Muchalls.

We are thus led up to understand the peculiar structure of the rocks forming the northern escarpment of the "newer gneiss," which I have already described macroscopically. My remarks, as heretofore, apply to those near Loch Maree; but I may add that through the kindness of Professor Lapworth and Mr. Teall, I have had the opportunity of examining collections from other districts in the north-west Highlands, to which my remarks, *mutatis mutandis*, apply. When examined microscopically, these newer gneisses, as I have said, perplex us by the evidence on the one hand of a fragmental structure, on the other of crystallization *in situ*. The former structure is most conspicuous in the immediate vicinity of the great overfold fault. A few miles back, the rocks often scarcely differ from a normal mica-schist or quartzose gneiss. Careful examination of a large number of specimens collected expressly for the purpose, illustrated by materials obtained in the Alps and compared with gneisses and schists collected from the admitted Hebridean series, have convinced me that the apparently fragmental structure of the "newer gneisses" is due to the crushing *in situ* and partial recrystallization of a varied series of fine-grained gneisses, mica-schists, &c. not unlike those at Gairloch, and not very different from those already mentioned from the Aberdeenshire coast. The peculiar "undulate structure," if I may so call it, of the constituents—often indicated especially by the mica, which differences these rocks from those already described—is due to the exceptional character of the pressure to which they have been exposed in the overthrust, which has caused a certain squeezing or dragging-out and lateral shearing of the constituents in the direction of apparent bedding. Thus the felspar grains, so marked a feature in some of the varieties, are simply remnants of original feldspars; and this accounts for their similarities to the feldspars of the Hebridean series. Some of the mica, but, I believe, by no means all, is of secondary origin; so also is some of the quartz; and probably any previous fragments of that mineral have received additions which are in crystalline continuity with them. The squeezing or rolling-out is especially conspicuous in one or two specimens taken from low down in the series in Glen Logan, the quartz granules having a peculiar dragged-out, clotted aspect, and having their optic axes approximately parallel, so as to produce a marked uniformity of tint when examined with the two Nicol's prisms.

The correctness of this explanation is supported by the examination of rocks formed by local crushing in the Hebridean series itself; one, discovered by Professor Lapworth and lent to me by Mr. Teall, is so similar, both in the hand-specimen and under the microscope, to some of my specimens from the neighbourhood of Glen Logan that, had it been sent to me as coming from the newer series in that locality, I should never have questioned it, and should only have remarked that "it had had a very hard pinch." This

specimen represents the condition of the Hebridean in the fold-fault at Loch Erriboll.

There may be, of course, various intrusive igneous rocks in this "newer series" of Loch Maree which have been crushed up like the gneisses and schists; but I think that the latter certainly predominate. It is also possible that portions of Palæozoic rocks may be faulted or folded in; but I feel certain that of them there is nowhere a great quantity, and that I saw none. Moreover I fully believe that, except very locally, there would be no real difficulty in distinguishing between the crushed gneisses and schists and the compressed Torridon Sandstone, quartzites, or other Palæozoic sedimentary rocks, provided only they be studied both in the field and with the microscope, and that the observer has duly qualified himself for the task by previous education.

Among the effects of these great pressures will undoubtedly be an elevation of the temperature of the rock, and this will facilitate mineral changes. But I think that this factor in metamorphism has been overestimated by some authors, and that it is of secondary rather than of primary value. Pressure alone, as shown by Dr. Sorby and others, is a most important agent in promoting the solution of minerals; and, when this ceases to act, deposition and crystallization may take place. Strain or pressure may be relieved, in the course of ages, by fracture and movement, by the settlement of the mass, and other causes. The excavation of valleys and denudation generally must produce important effects in this respect.

Contact-Metamorphism.

Rocks affected by contact-metamorphism (by which term we mean the alteration produced upon sedimentary rocks by the intrusion into them of igneous masses) while differing materially from those commonly called metamorphic—so much so, that the separation under the microscope of the one from the other is generally extremely easy—nevertheless present some suggestive resemblances. If we leave out of consideration the less extreme cases of contact-metamorphism, such as we find in the vicinity of most dykes and small intrusive masses, or where proximity to the surface of the earth has permitted a more rapid escape of heat, such, for instance, as abound in the Carboniferous series of Fifeshire; if we also pass by, as of comparatively simple character, the change of sandstone into quartzite, and the conversion of ordinary limestone into crystalline marble, and confine our attention to the argillaceous rocks, as of more complicated chemical composition, and to the cases where they are in proximity to large deep-seated intrusive masses, we find changes analogous to those which have been produced in the true schists, though, as I have said, presenting marked differences in structure. This analogy is not surprising; for probably the agents of change have been identical, viz. heat, pressure, water, working conjointly and for a considerable time.

I may illustrate the nature of the changes thus produced, by a brief sketch of the alteration in the Skiddaw slate as it approaches

the granite in the glen between that mountain and Blencathra. Of these rocks my lamented friend Clifton Ward has given us a good description accompanied by some valuable analyses*. The ground-mass of the well-known chialstolite slate, which is the first stage of the alteration of the ordinary Skiddaw slate, does not materially differ from that of an ordinary phyllite or satiny slate. It exhibits a banded structure, produced mainly, it seems, by the greater or less quantity of a very dark, probably carbonaceous, mineral, though there are other slight differences, such as in the size of the micaceous constituents, which, however, may possibly be due to the same cause. This ground-mass is composed of minute films of mica, probably sericite, with numerous mineral granules, which I do not attempt to name, but which are doubtless mostly alumina silicates. With these are mixed, in variable quantities, tiny granules of quartz (whether original or secondary I cannot say, probably both), and the black constituent—carbonaceous matter and iron-oxide. The mineral-banding, according to Mr. Ward, corresponds with the planes of cleavage. The only mineral of notable size and well-defined outline is the chialstolite; and I cannot help thinking that this belongs to a late stage in the alteration of the rock. The crystals are well defined externally, bear no marks of compression, and are fairly free from enclosures. Much of the carbonaceous matter seems to have been expelled during the growth of the crystals and forms a black external border. The filmy ground-mass is pushed aside, although the distortion of the layers does not proceed very far. Except, however, for these chialstolites the rock, as a whole, is still in an early stage of metamorphism. As we approach the intrusive granite, the rock becomes much indurated and evidently is more highly changed; it fractures readily across the cleavage-planes, so as to form the well-known "whetstone slate." On examining microscopic sections of these rocks, we find that the process of change appears to have been as follows:—The rock was at first a fine-grained mud (for the analysis shows that there cannot have been much free quartz). It must have been brought (probably after being cleaved) to a condition which allowed fairly free motion among its molecular constituents. Certain of these have combined to form well-defined crystals of a mica of the biotite group; others, a mica of the paragonite group; the black constituents have to a great extent disappeared; very numerous microlithic prisms, probably a subsilicate of alumina, have been formed. Numerous rather elongated elliptical spaces may be observed comparatively free from these prisms, the micas, and the black spots; these I think we may safely recognize as ill-developed crystals of andalusite, and there are a few more definitely crystalline (chialstolite?). These last two, as in the former case of the chialstolite, have to some extent extruded the more

* After more than one examination of the Lake district. I am obliged to say that I cannot find the slightest ground for the theoretical views of my friend as to the more important intrusive masses of igneous rocks being portions of the sedimentary rocks melted down. I believe that the cause of this error (as I hold it to be) was an over-estimate of the amount of metamorphism in the Borrowdale series.

minute constituents. The mica crystals, while they exhibit a slight tendency to a banded arrangement, lie about in all directions in the bands, and the same is true of the other minerals. There is some free quartz, but the granules are small and do not appear to be very abundant. Another specimen, taken from rather nearer the granite, exhibits a similar structure; but the mica flakes are slightly larger, so are the quartz granules, and the spots of andalusite are a little more clearly defined, and are yet more distinctly bordered by the mica. The process, in fact, of mineral segregation and crystal growth appears to have been slightly protracted. Another specimen, taken from rather nearer an exposure of granite, does not materially differ, except that it exhibits some bands comparatively free from andalusite, and consisting mainly of quartz and mica. A specimen taken within a yard of the granite contains but little andalusite, and consists mainly of quartz and mica with a few garnets. As, however, a portion of the slide resembles the others, I presume the mineral differences here are due to original composition (which, indeed, I inferred from the appearance of the rock in the field); hence the main distinction is, as before, the more perfect separation and insulation of the constituents. Lastly, in an actual contact-specimen, the mica flakes are yet larger, the andalusite, in parts, though not invariably, is rather more clearly defined, and there are some irregular spots of a mineral resembling staurolite*. The inferences which would be naturally drawn from the above description are confirmed by numerous other specimens which I have examined †. The process of change (which of course depends, in the first instance, on the original constitution of the rock) is somewhat as follows:—A very considerable proportion of the constituents are rendered capable of entering into new combinations. Suppose, then, the rock was originally (as probably in very many cases) a fine-grained mud or silt, consisting of kaolin, of felspar débris still retaining the alkaline constituents, of very minute quartz granules, perhaps with fragments of mica and more or less carbonaceous and ferruginous matter. Heat and pressure, in the presence of water, as shown by Daubrée's experiments, tend to separate silica from a silicate, so as to form free quartz and silicates with a lower proportion of silica. The alkaline constituents combine, in the one case, with some of the iron and the requisite silicates to form a potash-iron mica; in the other, they combine to produce a paragonite. Subsiliates of alumina are formed, such as andalusite, and the quartz set free crystallizes, sometimes perhaps independently, sometimes, no doubt, around original constituents as nuclei. Now this process of segregation is in many respects analogous to that of crystallization in certain of the igneous rocks, and I have observed that these quartz granules have commonly the rather rounded but slightly irregular outline which is characteristic of the felstone and some micro-

* Perhaps the higher temperature has allowed the iron to enter into combination with the alumina silicate.

† I have been kindly permitted to examine a fine series collected by Mr. Allport, and now in the British Museum, from Cornwall and other localities, and another still in his own possession.

granites. The same may be observed sometimes in certain schists ; but the latter commonly appear to have crystallized under pressure more definite in direction than is the case with these contact-metamorphic rocks. The structure in the schists may often be due to subsequent compression followed by recrystallization, but I doubt whether it is so in every case. In one other respect there is a marked difference between the contact rocks and the older metamorphic. In the former, felspar (of endogenous origin) is very rare, if not wholly absent. I have never seen an instance of it that was beyond question (except in the immediate vicinity of the contact-surface) ; generally it is wanting. Though often an analysis shows that there is enough of an alkaline constituent left in the mud to make a fair amount of felspar, still this is taken up by mica, and the alumina silicates (or subsilicates) are non-alkaline.

In this rough sketch I have omitted, for simplicity, several of the mineral changes, such as the formation of garnet, idocrase, magnetite or hæmatite, pyrite, graphite, because, *mutatis mutandis*, the same method of explanation would apply ; or such as the formation of epidote, which, indeed, may also result, like the introduction of carbonates, as a yet further change ; or of tourmaline, so abundant in many of the Cornish specimens, because I regard the last as exceptional and the result of a process of addition possibly subsequent to the intrusion, since it affects both the rocks. It is intended to show simply how far Nature in that part of her laboratory-work which we are permitted to contemplate, though at a distance, throws light upon that which is only a matter of inference. We see then that there are analogies between the contact-metamorphism and the regional metamorphism ; but the latter has some very marked differences from the former, chiefly in the presence of feldspars and, in most cases, in the greater size and definiteness of the mineral constituents*. Moreover contact-metamorphism, as we might expect, in its more marked effects, is a very limited phenomenon. Between the so-called schists and gneisses produced by it which I have seen, or between the silky slates, phyllites (or so-called schists) of Palæozoic or later age, in much-folded districts, and the true schists and gneisses, of either known or presumed Archæan age which I have been able to examine, there is a very wide gulf, which, notwithstanding all assertions to the contrary, I do not believe has yet been filled up by well-established transitional forms.

Progressive Metamorphism in a downward Direction.

It may, perhaps, be urged that, as the evidence of stratification decreases and the amount of mineral change increases as we proceed

* As these differences are so marked, it would be well to abstain from calling any of the rocks thus produced "mica-schists," &c. Dr. A. Geikie (Text Book, bk. ii. pt. ii. § 7) suggests the revival of the old name *Cornubianite*. This might well be done, provided it be understood that the alumina-silicate was, as a rule, not feldspar, but some subsilicate, such as andalusite ; or, having regard to the etymology of the term, and to the fact that tourmaline is very commonly the aluminous constituent of the Cornish "contact" rocks, we might define *Cornubianite* as essentially consisting of quartz, mica, and tourmaline, and revive the term *Proteolite* for rocks consisting essentially of quartz, mica, and andalusite.

downwards among the metamorphic rocks, the cause producing molecular change has operated in the reverse direction, and that in the gneisses and schists we have nothing more than ordinary sediments, which, in consequence of having been buried deep beneath superincumbent masses of sediment, have been exposed under great pressure in the presence of water to the action of a comparatively high temperature. This opinion has found favour with many, and is worthy of consideration; it is in the highest degree probable that some of the metamorphic rocks were once ordinary sediments; moreover agencies such as those just named could not fail to produce some effects, so that this may be the history—I would say, probably is the history—of some of the metamorphic rocks. But when to this proposition the corollary is added, “Therefore the metamorphic rocks may be strata which have been deposited in Palæozoic or even later times,” I am obliged to assert that, while admitting the abstract possibility, I have seen no direct evidence in its favour. All attempts to identify large groups of metamorphic rocks with strata of post-Archæan age have proved to be failures. Masses of Palæozoic rock have been buried deep, and exposed to the vertical pressure of two or three miles of superincumbent rock, besides lateral earth-thrusts, and the amount of mineral change produced, compared with that in a true mica-schist, is trivial. The Skiddaw slate is said to have been overlain by not less than twenty-five thousand feet of rock*, no small part of which was formed by volcanic agencies, and yet it is only metamorphosed in the neighbourhood of the granites. The Old Red Sandstones of South Wales have been buried beneath at least ten thousand feet of Carboniferous rock; but here, too, the change is only mechanical. Yet, if metamorphic rocks had been produced by the alteration in later geologic times of sediments of known date, we should expect to find a gradual upward transition from the metamorphosed to the unmetamorphosed rocks; but this is precisely what we do not commonly meet with, for below the latter there is generally an abrupt break. Rocks intermediate between schists and shales are far more rare than we should expect in Nature, supposing this hypothesis correct.

Selective Metamorphism.

By this is meant the variable effect of such agencies as pressure and heat on rocks originally of different mineral constitution, so that those composed of materials readily lending themselves to change undergo great alterations, while the more refractory retain their original characters. In the past, selective metamorphism has, I think, been overestimated, and has been invoked by myself equally with others too much as a *deus ex machina* to help us out of every difficulty. At the same time there is a certain truth in it, which must not be overlooked; and forgetfulness of this, even on the part of those who are in the habit of invoking it, has led sometimes to erroneous inferences as to the history of a rock and to comparisons between those which present essential differences. Thus in certain

* Ward, Mem. Geol. Survey, Lake District, p. 73.

rocks crystals of considerable size of such minerals as pyrite, magnetite &c., are readily formed. So are quartz and calcite, also hornblende, chlorite, epidote, various zeolites, garnet (generally microscopic), tourmaline in special circumstances, &c. In like way, pure limestone readily assumes a crystalline structure. Hence we find fairly crystalline limestones, and especially dolomites of Secondary or even later age. It is, however, noteworthy that any one of these presents marked differences from a rock of Archæan age which has a like chemical composition. The most crystalline dolomites from the English Permians or from the Alpine Secondary strata, the limestones from the latter and from Socotra (probably Tertiary), differ greatly from any which are certainly of Archæan age, and, if I mistake not, there are even differences between the older and younger of the last. Such minerals as mica, some varieties of pyroxene, quartz—not obviously of fragmental origin—garnet, not to name others, are frequent in crystalline limestones of Archæan age, but are rare in those certainly of later date, in which the non-calcareous constituents still appear unchanged. In reference to this point I may remark that it will surprise me if the comparatively late date assigned by some geologists to the marbles of Carrara proves to be correct.

The facility with which crystalline quartz is deposited, in the manner often described, causes a sandstone to be readily converted into a quartzite; but I may remark that for this change it seems to be essential that the rock should be very clean, that is, the quartz-grains should be as nearly as possible free from all earthy or ferruginous admixture. Clay, indeed, appears to be generally a very refractory material, except sometimes under great pressure, when silica is separated, and minute micaceous minerals are formed from the residue. As I have said, clay remains seemingly unaltered in some crystalline limestones and quartzites, and, if abundant, certainly impedes crystallization. From what I have seen, I am led to think that mixtures of different mineral substances and different-sized particles do not so readily change as those which are homogeneous. Thus I have noticed that, in the same series, gritty slates seem a little less altered than those of finer and more uniform materials.

We find a good example of this variation in the Palæozoic group near Loch Maree. The purest quartzites are the most highly altered. The quartzites, as a whole, are more metamorphosed than the dirty limestone above or the heterogeneous Torridon Sandstone below. In the case of the last named we might have expected that quartz would have been attracted to quartz, felspar to felspar, mica to mica, hornblende to hornblende. These accretions are familiar in the case of quartz, they have been claimed for felspar and hornblende, and they are in accordance with the principle of elective affinity. Thus we should expect that the conversion of a suitable arkose into a gneissic rock would be comparatively easy. It is quite possible that this may be the origin of some gneisses; but in the case of the Torridon Sandstone, we do not see much approach towards it.

Moreover, when this rock has been exposed to great pressure, the result appears to differ from that afforded by a gneiss under similar circumstances. The quartzites also, when similarly treated, still retain a certain individuality and differ from the quartz-schists of presumed Archæan age. Apart, then, from the fact that the "newer gneiss series" of the North-west Highlands retains its distinctive features, and presents us with similar gneissoid rocks, not only in regions where Torridon Sandstone is largely developed, but also in those from which it is practically absent, I am of opinion that even if newer materials are locally infolded with strata of earlier date, it will, as a rule, be possible, on careful examination, to distinguish the crushed-out Archæan from the crushed-out Palæozoic members.

Age of the Alpine Cleavage-foliation.

It may be asked What is the date of the secondary or cleavage-foliation in the Alps? In the district of which I have spoken, it preserves a uniform direction over considerable areas, and its strike appears to coincide generally with the strike of the cleavage in the Secondary rocks, and that of the great folds by which the whole region is affected. Hence it would seem to be post-Secondary and probably post-Eocene. This, however, may not be universally true; for I know of cases which lead me to suspect that a cleavage-foliation existed prior to the great period of subsidence, and the upraising of the Alps was a more complicated process than is sometimes supposed. On this question, however, I do not at present feel qualified to enter. I pass it by, merely remarking that the development of minerals along the crush-planes only takes place on an important scale in rocks originally crystalline, and even there, although the general effect is plain, the individual mineral constituents by which it is produced are for the most part extremely minute. It is a remarkable fact that, in a certain sense, a sheen surface is often more conspicuous to the naked eye than it is under the microscope.

Age of the Gneisses and Crystalline Schists.

A few years since, the following sentence (which is quoted from a very recent text-book) would have been accepted by most geologists without hesitation:—"There are wide regions in which crystalline schists (*a*) overlie fossiliferous strata*, or (*b*) contain intercalated bands in which fossils occur, or (*c*) pass either laterally or vertically into undoubted sedimentary strata." This conclusion is "confidently drawn" from a series of statements of which, to my personal knowledge, several are uncertain, others are either incorrect or inadequate for the purpose. I must again repeat that observations on such questions as the relations of the crystalline schists and stratified rocks, as to apparent similarities or dissimilarities, are of little value unless they have been made by observers well practised not only in the field but also in the use of the microscope; hence the statements of the best observers, in what we may call premicroscopic days,

* The author means in chronological sequence, not by inversion or overthrust.

cannot now be regarded as conclusive; and even the opinion of a skilled microscopist may be of little value unless he has served a long apprenticeship to this particular kind of work. Its problems are far more difficult, far more complicated, far more misleading than those which present themselves in the study of the igneous or of the ordinary sedimentary rocks. On this I may venture to insist, as I can speak from personal experience. Five years, at least, of fairly hard work have shown me how many of my earlier impressions were incorrect, and how much I have yet to learn in regard to this vast, but strangely fascinating, subject; but they have also given me some confidence in regard to certain general results, which entitles me to demand a rigid proof of any assertion which makes against them. I will therefore briefly recapitulate the evidence as to the age of the crystalline rocks in the districts which I have already described. In the Alps the *schistes lustrées** (or uppermost group of schists) have by some geologists been claimed even as altered Trias. As the above name appears to me to have been used rather inclusively, it is possible that some portions of the group may be representatives of Palæozoic or Mesozoic strata. In such case, however, it will be found that they are but slightly altered, and so have no right to be included in it. Confining myself to the true schists, such as have been described in a former part of this address, I can only say that they must be much older than any rock to which we can certainly assign a date. The Jurassic and Triassic strata of the Alps are, at most, but slightly altered, even where they have been most tightly nipped between huge pincers of crystalline rock. It is a misuse of the term, as I have defined it, to call them *schists*. Sericite and other secondary minerals have undoubtedly been developed; but these (where of any significance) are on the most minute scale, and one of these "phyl-lites" has hardly more relation to one of the crystalline mica-schists than a Hanoverian medal has to a genuine sovereign. In the less disturbed districts the Secondary strata rest upon the edges of the crystalline schists, and both are in their normal condition. Basement conglomerates and breccias in the former contain fragments of the different types of crystalline rocks, from the coarser gneisses to some at least of the later schists. In like manner the Carboniferous rocks of the valley of the Rhone exhibit practically no real approach to the crystalline schists. To assert that "at Vernayaz, near Martigny, the Carboniferous strata can hardly be separated from the schists," is only thus far true, that as in places the base of the Carboniferous series is a conglomerate or arkose, composed of detritus from the gneiss, and both have undergone great compression, and have been somewhat decomposed, a spot can now and then be found where it is difficult to draw the line with absolute precision; but, as a rule, although some secondary minerals, generally minute in size, have, under favourable circumstances, been developed in the Carboniferous series, the two groups are perfectly distinct. This

* These appear to be identical with the "Bündner Schiefer" of German-speaking geologists, those which I have called "Brown-bedded" schists.

district, in fact, would prove too much for the modern advocate of regional metamorphism; for he would have to explain the rapid passage from a rather coarse gneiss to an ordinary black slate, besides accounting for the fragments of gneiss in the intervening zone.

I may also remark, after careful examination of a large number of specimens, that the Alpine gneisses and schists, including even the latest of those described above, seem to have assumed a thoroughly crystalline condition before being subjected to the great pressures, of which, in some cases, they now retain such conspicuous marks. In regard to the coarser gneisses and older rocks, this obviously follows from what I have said; but, I believe, it is no less true of the Tremola and later schists. The larger flakes of mica, the garnets, the andalusites, cyanites, and other subsilicates which occur porphyritically in finer-grained schists, possibly also the actinolite of the Tremola schists (though here, as we might anticipate from a variety of hornblende, there is something to suggest a recrystallization of the constituents), appear to be anterior in date to the great earth-movements. It is true that we cannot be certain that the latter were pre-Tertiary, but as there is good reason to believe that all the crystalline schists are pre-Carboniferous, the epoch of their crystallization is thus thrown very far back, because the considerable size of many of the above minerals, and the fact that inclusions of other minerals are not extraordinarily numerous, shows that there must have been much free movement among the constituent molecules of the rock, and indicates that their aggregation must have taken place under conditions very different from those of ordinary pressure- or contact-metamorphism.

The rocks also of the Ardennes, in the valley of the Meuse, are often quoted as exhibiting instances of regional metamorphism. These I know well, and have no hesitation in saying that the statement is only true in the most limited sense of the words. It is quite true that certain secondary minerals have been developed in the green and black glossy slates, presumably of Cambrian age; but between these and the normal mica-schists, there is almost as wide a gap as between a slate from near Torcross and a schist from the Lizard.

In Pembrokeshire the conglomerate at the base of the Cambrian contains occasionally materials which, according to the ordinary rules of geological reasoning, must have been derived from the so-called Dimetian rock, as well as rare fragments of crystalline schists not now exposed at the surface. The underlying tuffs (Pebidian) only exhibit a development of mica on a very minute scale, and thus they are no more than embryonic mica-schists. In Anglesey, conglomerates which cannot be newer than basement Ordovician, and may be much older, contain indubitable fragments of the coarse granitoid gneisses and some of the schists of that island. The coarser beds of presumably Ordovician age in Cornwall afford indications of pre-existent schists. The Charlton Hill conglomerate, near the Wrekin, which is certainly much older than the Lingula Flags and probably pre-Cambrian, contains Malvernian rocks and schists of Archæan

types. In the Highlands, notwithstanding the structural changes which some of the Archæan rocks have undergone in subsequent earth-movements, they can, as a rule, be distinguished from the Palæozoic strata, and I have no doubt that patient work by properly trained observers will prove the same to be true of other districts. As in the Alps, there will be occasional difficulties, small areas where Nature has obliterated all distinctive markings; but these prove no more than do gaps in an inscription, or obliterations of any kind. If among a large "hoard" of shillings of the latter part of the seventeenth century one were found worn perfectly smooth, no antiquary would think this an argument for its being a coin of George III.

It is often asserted that fossils have been found in schists. In some cases mere imitative markings have been mistaken for organisms; in others, if the fossiliferous beds are not infolded between older crystalline rocks, selective metamorphism has run wild, and its advocates will find the old saying true, *qui prove trop, ne prove rien*; in others the rocks are not schists but slates. One case only requires serious attention, the Norway micaceous schist with Silurian fossils. Of this I have hitherto failed to obtain specimens for examination, but from what I can learn, the rock is one of those which is far nearer to the group of glossy slates than it is to the true mica-schists. I may add that the theory of a regular upward succession from the crystalline series to this fossiliferous rock is, on Herr Reusch's own showing, in the highest degree improbable. We are, then, in this position, that the asserted equivalence of gneiss and crystalline schists with Palæozoic or later strata has in no single instance been the subject of rigid proof; that the evidence produced in some cases rests only on a vague use of terms, in others has broken down hopelessly on examination, so that while it would be rash in our present state of knowledge to assert that this can never be, we have a right to assume its improbability, to demand the clearest proof, and a severe cross-examination of the witnesses.

Origin of the Archæan Rocks.

If, then, as seems more probable, the great masses of gneisses and crystalline schists are anterior to the Palæozoic period, the question naturally suggests itself, Under what circumstances were they produced? If they differ materially from any rocks which have been subsequently formed, it seems a fair inference that this is due to a difference of environment; if we perceive the nearest approach to them in rocks which have been exposed, in the presence of water, to exceptional heat or pressure, or to both, we should suppose that they were formed at higher temperatures and under greater pressures, in short under circumstances more favourable to chemical changes and mineral development. On the hypothesis that this globe was formerly an incandescent mass, such a state of things must have once prevailed; and as it cooled by the gradual radiation of heat into space, there must have been an approach, probably at first somewhat rapid, then more gradual, to the comparatively uniform condition

which has prevailed since life has left its trace on the pages of the great Stone Book of Nature.

Various attempts have been made to describe the genesis of the earlier Archæan rocks, but at present, as it appears to me, we can do little more than vaguely conjecture. On the one hand, it seems clear that many gneisses are formed after compression from granites, many hornblende-schists from dolerites, and possibly some other schists may be the result of mineral change in igneous rocks of suitable constitution. At the same time, as I have shown, some even among the oldest gneisses exhibit structures which appear to distinguish them from granites, and the presence of limestones suggests at any rate some kind of stratification or stratified precipitation. The indications of sedimentation become more clear as we ascend in the series, so that we cannot avoid assigning a sedimentary origin to many of the bedded gneisses, schists, limestones, quartzites, &c. Some have suggested that among these oldest gneisses we have representatives of the earliest crust of the globe, though modified by subsequent mineral change, and that we may see in them the roots of primæval volcanoes and metamorphosed remnants of their associated beds of ashes. This may well be, for we should expect that for a time, after the first solidification of the globe, volcanic action (as in the phase of history stereotyped by the moon) would be more universal and on a grander scale than it has ever been since. But, unfortunately, we have little to guide us as to the nature of the structures which would be assumed by volcanic materials under circumstances such as these.

A very learned and ingenious attempt has recently been made by Dr. Sterry Hunt to explain the origin of the crystalline rocks. By his hypothesis, termed the *Crenetic*, the primary crust of the globe, last solidified by cooling from a state of igneous fluidity, is supposed to have been a basic quartzless rock. This is conceived to have been fissured and rendered porous during crystallization and refrigeration, so as to have become permeable to considerable depths to the waters subsequently precipitated upon it. By their action, the crystalline stratiform rocks (the fundamental granites and the granitoid gneisses) were derived from it. Subsequent disturbances would corrugate and elevate these, giving rise to fissures from which the underlying basic stratum would be erupted, and from the subaerial decay of the two types new factors would be introduced into the rock-forming processes, and the more variable later gneisses and schists produced. This hypothesis, no doubt, accounts for many facts, and is a suggestive and valuable contribution to the solution of a complicated problem. At the same time, I must remark that the author regards the subject too exclusively from the point of view of a chemist, and takes more for granted than appears to me warranted by the facts of Nature, as learnt in the field, or from study of rock-structures under the microscope; but while I think some of the petrological statements dubious, some of the proposed stratigraphical orders improbable, and some of the generalizations too sweeping, I must say that the tendency of the evidence which he has brought together so labori-

ously and marshalled so skilfully, is in favour of the idea that the crystalline schists and gneisses were formed in Archæan ages under conditions which have never subsequently recurred in any large area of the globe.

My own investigations, as will have been inferred from the foregoing remarks, have led me to consider a like conclusion as the most probable. On the one hand the phenomena of contact-metamorphism, on the other those of pressure-metamorphism, throw considerable light on the genesis of crystalline schists. But they afford only a partial explanation; each illustrates rather than elucidates. Something also may be learnt from the phenomena of veins—there, for example, the formation of felspar, apparently so difficult in the other two cases, appears to be easy. Still something more seems wanting, some cause or causes, universal rather than local, general rather than exceptional, the results of which in Palæozoic and later periods have been imitated rather than equalled. Heat, water, pressure, have, no doubt, had their share in producing the result, but they appear to have cooperated over vast areas of the earth's crust in a way that seems inconceivable under existing conditions.

Transitional Forms.

It must be remembered that whichever hypothesis be adopted to explain the origin of the gneisses and crystalline schists, whether we regard them as results of conditions prevalent only in Archæan times, or as due to regional metamorphism acting on Palæozoic or later deposits, transitional forms must exist. On the one hand there would be a gradual approximation to the conditions which prevailed at the commencement of the Palæozoic series, which epoch, it must be remembered, cannot be supposed to correspond with any universal break in the history of the globe. On the other, we should expect to find every graduation, from the most marked effects of regional metamorphism till it became practically inoperative. Thus some of the rocks in our own island which occur beneath the base of the Cambrian, those properly called Pebidian, do not, to use the ordinary phrase, exhibit much more metamorphism than those next above in succession. But, as it happens, in those regions known to myself, these transitional forms are rare, and it would seem as if, in our own island, while the concluding page was torn away from the Archæan volume, a whole chapter at least was missing from near the end, of which, however, the careful searching of conglomerates may restore to us some fragments. The break seems even greater in those parts of Europe and North America of which I have any knowledge. I think, however, that this rarity of transitional forms—of hypometamorphic rocks—is some argument in favour of the Archæan age of gneisses and crystalline schists; for if they were the result of regional metamorphism acting on sediments of later date, transitional forms should be common. Instances are numerous where the Palæozoic rocks have been depressed to great depths and buried beneath thousands of feet of later deposits, or have been exposed to the action of immense lateral pressure; yet in any case where the

non-Archæan age of the deposit is known, we find that the results of metamorphism are comparatively slight, and that the schistose rock thus produced is very far removed from a true schist. Further, when these are underlain by gneisses and crystalline schists, as in the Alps, there is not a gradual transition into the latter, but an abrupt change. Now if a gradual transition could only be found as we passed downwards from the lowest Palæozoic rocks through the upper part of the Archæan series, instances of this (as representing one period only of the earth's history, and one of which the rocks were less resistant than their highly crystalline predecessors) would naturally be rarer.

The Correlation of Archæan Rocks.

Let us now see what lithological parallels suggest themselves between the rocks of the regions noticed in this address. In doing this we must as far as possible make allowance for the results of subsequent compression and crushing, and found our comparisons either upon uninjured specimens which may sometimes be found, or those in which what we may term "a restoration" is not difficult to the practised eye. We may also, if due caution be exercised, use for comparison rocks which, after similar treatment, present marked lithological identities.

There is a very close resemblance between the Laurentian gneiss of Canada and the Hebridean of Scotland (in which may be included certain rocks of the Central Highlands*). In many cases I could only distinguish a Canadian from a Scotch specimen by its label. Many similarities to these may be noted in the coarse gneissic and granitoid rocks of Anglesey, and with them we may venture to compare the granitoid rocks near Caernarvon. Some of the gneisses of the Malvern Hills and the Wrekin district seem to me only to exhibit varietal differences; and those which I have described as occurring in the lowest part of the Alpine series (1) and (2), notwithstanding differences in colour and more indications of an igneous origin, appear to me generally identical. The coarse gneisses of the Schwartzwald and Odenwald, and other districts in Central Germany, have also a Laurentian facies, which, however, is generally admitted.

The resemblance between the Lepontine gneisses (3) and Casanna series (4) of the Alps and the Montalban series of America is very striking; and to these we often find close parallels in the more micaceous gneisses and mica-schists, often rich in garnets, of the Highlands. I have seen specimens of so-called Huronian of similar types. It is possible that some of the so-called gneisses (fine-grained) of Anglesey may be correlated here; but my specimens (including some of the rock claimed as hälleflinta) would be more properly designated quartzose mica-schist, and in general structure remind me of Alpine rocks that lie at a slightly higher horizon. It is very probable that some of the quartzose schists abundant in the Central Highlands (*e. g.* on the Highland Railway above Blair Athol

* *E. g.* from near Loch Shiel, as described by Dr. Hicks, whom I have to thank for specimens (see Q. J. G. S. vol. xxxix. p. 155).

and about Achnasheen) occupy this position in the series. The greenish and lead-coloured schists, with quartzites, in Anglesey, the Cornish schists (though perhaps these are rather older), and those of South Devon, present many resemblances to members of the uppermost zone of the metamorphic rocks of the Alps; and to these I should refer some of the more crystalline Huronians. The remainder of the Huronians and the red felstones of Canada closely resemble the true Pebidians (including the rhyolites of North Wales).

It has been often urged that these comparisons are idle; that they must be made with extreme caution no one feels more strongly than myself. I think observers have frequently been much too hasty in inferring similarities and asserting discordances. I should make every group as inclusive as possible, and I shrink, almost nervously, from proposing distinctive names. But what is our position? We assert without fear of contradiction, that every attempt to show that any of these gneisses and schists are metamorphic strata of Palæozoic age has broken down on examination. They are always much older than any rock which we can date; some are indubitably long anterior to the Cambrian epoch. So complete has been the failure of these attempts, that we have a right to demand as unprejudiced judges that all the evidence in their favour should be regarded with suspicion, like that of discredited witnesses. Schists and gneisses *may* be metamorphosed Palæozoic shales, but the *onus probandi*, according to all the rules of evidence and of reasoning, now lies upon the person who asserts it, and there is so much against the antecedent probability of such an identification, that it can only be admitted on the very clearest evidence.

If, then, these schists and gneisses are Archæan or Azoic or Eozoic (I regard the name as a very secondary matter), if they are mostly long anterior to the Cambrian, and if in various regions we observe increased metamorphism in a downward direction, and progressive evidence of some kind of stratification in an upward, together with a stratigraphical succession and lithological correspondences not rare but frequent, it seems to me that, as we can have no other means of comparison or correlation, we may fairly use this as a working hypothesis. It will, at any rate, facilitate our labours, and cannot, I think, do anything but good, if we are careful to remember that it is only an hypothesis, and so apply to it honestly the test of every fact that in the process of our work we can regard as established.

If these strata are of great antiquity, if they are the record of a very early period in the earth's history in which at first a condition of things wholly different from the present must have prevailed, and if there was a gradual approach to those more in accordance with the present, it is highly probable that similarities of environment, and uniformities of deposits would prevail over areas far larger than is now the case. Chemical action, at a time when the earth's crust and atmosphere were at a higher temperature than in later days, would be more intense than now; precipitation and sedimentation would differ widely in their results when the solvent agents differed and

the materials operated upon were more uniform. Homotaxis is recognized as a great principle in the life-history of the earth; that a like order should prevail in the development of its earliest rocks, does not seem an improbable hypothesis.

The one path is supported by a considerable number of ascertained facts and *a priori* probabilities inferred from physical considerations; the other is strewn with the débris of mistaken observations and exploded hypotheses. The one, though strait and hard, offers some hope of leading us at last to the light of truth; the other, though at first it seemed broad and easy, has been proved to be the way of darkness and of error. Those who, like myself, have been at the pains of testing the asserted evidence in its favour, know how it has been bolstered up by incorrect observations, unproved assertions, untested assumptions, and inferences founded sometimes on superficial similarities, sometimes on a mere juggling with words, which is more worthy of the schools of the sophists than of the earnest searcher after truth. If progress is to be made in this branch of petrology, if the veil that hangs over the first beginning of this globe's history is ever to be raised, it must be done by free and independent investigation, by the most careful scrutiny of nature, by strict attention to the meaning of words, and by the honest and unflinching use of those processes of induction which are the foundation of all true science.

My last duty is to thank you for the patience with which you have listened to this long and somewhat discursive address, and, even more heartily, for the unvarying kindness which, during the last eight years, and especially since I became your President, I have received from the Officers, the Council, and the other Fellows of the Society. I retire from office with a deep sense of the honour which you have conferred upon me, and the friendly spirit in which you have received my endeavours to serve the Society. So pleasant has the work been made that I might relinquish the chair with some regret did I not greet as my successor a valued friend and colleague, who will fulfil its duties with no less zeal, and who, as a geologist, is more worthy than myself of so great a distinction.

February 24, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

William Barns Kinsey, Esq., M. Inst. C.E., 9 Carteret Street, Queen Anne's Gate, Westminster, and Henry Maurice Platnauer, Esq., Assoc. R.S.M., 5 Mount Terrace, York, were elected Fellows; and Professor Juan Vilanova y Piera, The University, Madrid, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On two Rhætic Sections in Warwickshire." By Rev. P. B. Brodie, M.A., F.G.S.
2. "On the Basement-beds of the Inferior Oolite of Gloucestershire." By E. Witchell, Esq., F.G.S.
3. "On the Pliocene Beds of St. Erth." By Percy F. Kendall, Esq., and Robert G. Bell, Esq., F.G.S.

The following specimens were exhibited:—

Rock-specimens and fossils, exhibited by E. Witchell, Esq., F.G.S., in illustration of his paper.

Fossils from the Pliocene Beds of St. Erth, exhibited by P. F. Kendall, Esq., and Robert G. Bell, Esq., F.G.S., in illustration of their paper.

Six large water-colour pictures of various places of geological interest, exhibited by the artist, P. Brannon, Esq.

March 10, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

Jonathan C. B. P. Seaver, Esq., Geelong, near Mudgee, N. S. Wales, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Alteration of coarsely Spherulitic Rocks." By Grenville A. J. Cole, Esq., F.G.S.

2. "Account of a Well-sinking made by the Great Western Railway Company at Swindon." By Horace B. Woodward, Esq., F.G.S. With Lists of Fossils, by E. T. Newton, Esq., F.G.S.

The following specimens were exhibited:—

Rock-specimens and microscopic sections, exhibited by G. A. J. Cole, Esq., in illustration of his paper.

Rocks and fossils from the Swindon Well, exhibited by the Geological Survey.

March 24, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Genus *Diphyphyllum*, Lonsdale." By James Thomson, Esq., F.G.S.*

2. "On additional Evidence of the Occurrence of Glacial conditions in the Palæozoic Era, and on the Geological Age of the Beds containing Plants of Mesozoic type in India and Australia." By Dr. W. T. Blanford, F.R.S., Sec. G.S.

The following specimens were exhibited:—

Specimens of *Diphyphyllum*, exhibited by James Thomson, Esq., F.G.S., in illustration of his paper.

Six specimens of *Conularia*, and three small pebbles from the Salt Range, exhibited by A. B. Wynne, Esq., F.G.S., in illustration of Dr. Blanford's paper.

April 7, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

Edward George Aldridge, Esq., Trevor House, 18 Talbot Road, Bayswater, W.; Charles Brownridge, Esq., Horsforth, near Leeds, Yorkshire; James Dennant, Esq., Hamilton, Victoria, Australia; Charles Lane, Esq., "Public Ledger" Office, 6 St. Dunstan's Passage, E.C.; Prof. H. Carvill Lewis, Philadelphia, U.S.A.; and William Matthews, Esq., Assoc. Memb. Inst. C.E., Municipal Offices, Southampton, were elected Fellows of the Society.

* This paper has been withdrawn by the Author, by permission of the Council.

The List of Donations to the Library was read.

The following communications were read :—

1. "On Glacial Shell-beds in British Columbia." By G. W. Lamplugh, Esq. Communicated by Clement Reid, Esq., F.G.S.
2. "On a Lower Jaw of *Machærodus* from the 'Forest-bed,' Kessingland." By James Backhouse, Esq., F.G.S.
3. "A Contribution to the History of the Cetacea of the Norfolk 'Forest-bed.'" By E. Tulley Newton, Esq., F.G.S.

The following specimens were exhibited :—

A series of Plant-remains from the Cromer Forest-bed, exhibited by Clement Reid, Esq., F.G.S.

Specimens from the Shell-beds in British Columbia, exhibited by G. W. Lamplugh, Esq., in illustration of his paper.

Specimens from the "Forest-bed" exhibited by James Backhouse, Esq., F.G.S., and E. Tulley Newton, Esq., F.G.S., in illustration of their papers.

April 21, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

Henry Fisher, Esq., 30 Abingdon Street, Blackpool; Frederick Edwin Harman, Esq., care of Messrs. Dunster and Chapman, 1 Henrietta Street, Cavendish Square; Henry Johnson, Esq., Trindle Road, Dudley; Edward Alloway Pankhurst, Esq., 12 Clifton Road, Brighton; and Henry Woolcock, Esq., Memb. Inst. C.E., Rickerby House, St. Bees, near Carnforth, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced the changes made in the Staff of the Society, and the appointment of Mr. Francis E. Brown as an Assistant.

The following communications were read :—

1. "On a certain Fossiliferous Pebble-band in the 'Olive group' of the Eastern Salt Range, Punjab." By A. B. Wynne, Esq., F.G.S.
2. "On the Phosphatic Beds in the Neighbourhood of Mons." By M. F. L. Cornet, For.Corr.G.S.

The following specimens were exhibited :—

Six specimens of *Conularia* and three small pebbles from the Salt Range, exhibited by A. B. Wynne, Esq., F.G.S., in illustration of his paper.

A series of specimens from the Phosphatic beds of Mons, exhibited by M. F. L. Cornet, For.Corr.G.S., in illustration of his paper.

May 12, 1886.

Prof. J. W. Judd, F.R.S., President, in the Chair.

Matthew Blair, Esq., Oakshaw, Paisley, was elected a Fellow, and Professor H. Rosenbusch, of Heidelberg, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

A series of specimens from the Phosphatic beds of Mons, which were exhibited by M. F. L. Cornet, Forr.Corr.G.S., in illustration of his paper read on the 21st April, were presented by him to the Society's Museum.

The following communications were read :—

1. "On the Maxilla of *Iguanodon*." By J. W. Hulke, Esq., F.R.S., F.G.S.

2. "Notes on the Distribution of the Ostracoda of the Carboniferous Formations of the British Isles." By Prof. T. Rupert Jones, F.R.S., F.G.S., and J. W. Kirkby, Esq.

3. "Note on some Vertebrata of the Red Crag." By R. Lydekker, Esq., F.G.S.

4. "The Pleistocene Succession in the Trent Basin." By R. M. Deeley, Esq., F.G.S.

5. "On the Existence of a Submarine Triassic Outlier in the English Channel off the Lizard." By R. N. Worth, Esq., F.G.S.

The following specimens were exhibited :—

A specimen of the greater portion of the left Upper Jaw of *Iguanodon*, exhibited by J. W. Hulke, Esq., F.R.S., F.G.S., in illustration of his paper.

Specimens of remains of Vertebrata from the Red Crag, exhibited by R. Lydekker, Esq., F.G.S., in illustration of his paper.

A series of specimens of the Pleistocene deposits of the Trent basin, exhibited by R. M. Deeley, Esq., F.G.S., in illustration of his paper.

May 26, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

John Allan Brown, Esq., 7 Kent Gardens, Ealing, W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "Further Proofs of the Pre-Cambrian Age of certain Granitoid, Felsitic, and other Rocks in North-western Pembrokeshire." By Henry Hicks, M.D., F.R.S., F.G.S.

2. "On some Rock-specimens collected by Dr. Hicks in North-western Pembrokeshire." By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

3. "On the Glaciation of South Lancashire, Cheshire, and the Welsh Border." By Aubrey Strahan, Esq., M.A., F.G.S., H.M. Geological Survey. By permission of the Director-General.

The following specimens were exhibited:—

A series of specimens and microscopic rock-sections from North-western Pembrokeshire, exhibited by Dr. H. Hicks, F.R.S., in illustration of his and Prof. Bonney's papers.

A bar of wrought-iron showing two series of crystalline cleavage-planes at right angles to each other, exhibited by James Love, Esq. F.G.S.

June 9, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the first time in conformity with the Bye-laws, Sec. VI. B, Art. 6, in consequence of the non-payment of the arrears of their contributions:—James Duigan, Esq., Henry Fisher, Esq., Rev. Edouard Méchin, Thomas Parton, Esq., Dr. George Rogers, Lt.-Col. J. D. Shakespear, E. Simpson-Baikie, Esq., Rev. T. E. Woodhouse, and James Wood Mason, Esq.

The following communications were read :—

1. "On the Volcanic Rocks of North-eastern Fife." By James Durham, Esq., F.G.S., with an Appendix by the President.
2. "On some Eruptive Rocks from the Neighbourhood of St. Minver, Cornwall." By Frank Rutley, Esq., F.G.S.
3. "The Bagshot Beds of the London Basin." By H. W. Monckton, Esq., F.G.S., and R. S. Herries, Esq., B.A., F.G.S.

The following specimens were exhibited :—

Rock-specimens and microscopic sections, exhibited by Prof. J. W. Judd, F.R.S., Pres.G.S., and James Durham, Esq., F.G.S., in illustration of their paper.

Rock-specimens and microscopic sections, exhibited by Frank Rutley, Esq., F.G.S., in illustration of his paper.

Fossils and specimens from the Bagshot Beds, exhibited by H. W. Monckton, Esq., F.G.S., and R. S. Herries, Esq., F.G.S., in illustration of their paper.

June 23, 1886.

Prof. J. W. JUDD, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the second time in conformity with the Bye-laws, Sec. VI. B, Art. 6, in consequence of the non-payment of the arrears of their contributions :—James Duigan, Esq., Henry Fisher, Esq., Rev. Edouard Méchin, Thomas Parton, Esq., Dr. George Rogers, Lt.-Col. J. D. Shakespear, E. Simpson-Baikie, Esq., Rev. T. E. Woodhouse, and James Wood Mason, Esq.

The President announced that he had received from Prof. Barrois an intimation that the Geological Society of France would hold a special country meeting in the District of Finistère from the 19th to the 28th of August next, during which a variety of interesting excursions would be made under the guidance of MM. Barrois, Davy, and Lebesconte. Prof. Barrois, in writing, expressed the pleasure which it would give the Members of the Geological Society of France if they were joined by some of their English *confrères*, but at the same time stated that as the accommodation for travellers was limited in the district, he would be glad to have timely notice from any one intending to take part in the meeting.

The following communications were read:—

1. "On some Perched Blocks and Associated Phenomena." By Prof. T. McKenny Hughes, M.A., F.G.S.
2. "On some derived fragments in the Longmynd and newer Archæan Rocks of Shropshire." By Dr. Charles Callaway, F.G.S.
3. "Notes on the Relations of the Lincolnshire Carstone." By A. Strahan, Esq., M.A., F.G.S.
4. "The Geology of Cape-Breton Island, Nova Scotia." By Edwin Gilpin, Esq., Jun., A.M., F.R.S.C., F.G.S., Inspector H.M.'s Mines.
5. "On the Decapod Crustaceans of the Oxford Clay." By James Carter, Esq., F.G.S.
6. "Some Well-sections in Middlesex." By W. Whitaker, Esq., B.A. Lond., F.G.S.*
7. "On some Cuprififerous Shales in the Province of Houpeh, China." By H. M. Becher, Esq., F.G.S.
8. "The Cascade Anthracitic Coal-field of the Rocky Mountains, Canada." By W. Hamilton Merritt, Esq., F.G.S.
9. "On a new Emydine Chelonian from the Pliocene of India." By R. Lydekker, Esq., B.A., F.G.S.
10. "On certain Eocene Formations of Western Servia." By Dr. A. B. Griffiths, F.R.S.E., F.C.S. Communicated by the President.

The following specimens were exhibited:—

Rock-specimens and microscopic sections, exhibited by Dr. C. Callaway, F.G.S., in illustration of his paper.

Specimens of Decapod Crustaceans from the Oxford Clay, exhibited by James Carter, Esq., F.G.S., in illustration of his paper.

Specimen of an Emydine Chelonian from the Pliocene of India, exhibited by R. Lydekker, Esq., F.G.S., in illustration of his paper.

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ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

SESSION 1885-86.

I. ADDITIONS TO THE LIBRARY.

1. PERIODICALS AND PUBLICATIONS OF LEARNED SOCIETIES.

Presented by the respective Societies and Editors, if not otherwise stated.

Academy. Nos. 686-712. 1885.

— . Nos. 713-737. 1886.

Adelaide. Royal Society of South Australia. Transactions and Proceedings and Report. Vol. vii. 1883-84. 1885.

J. Stirling. Notes on a Geological Sketch-Section through the Australian Alps, 1.—S. Dixon. Notes on the supposed Coal-beds of the Fitzgerald River, 9.—R. Tate. Notes on the Physical and Geological Features of the Basin of the Lower Murray River, 24.

Analyst. Vol. x. Nos. 112-117. 1885.

— . Vol. xi. Nos. 118-122. 1886.

Annals and Magazine of Natural History. Ser. 5. Vol. xvi. Nos. 91-96. 1885. *Purchased.*

S. H. Scudder. Notes on Mesozoic Cockroaches, 54.—R. Kidston. On the Relationship of *Ulodendron*, Lindley and Hutton, to *Lepidodendron*, Sternberg; *Bothrodendron*, Lindley and Hutton; *Sigillaria*, Brongniart; and *Rhytidodendron*, Boulay, 162, 239.—F. Toula and J. A. Kail. On a Crocodile-skull from the Tertiary Deposits of Eggenburg in Lower Austria, 236.

— . — . Ser. 5. Vol. xvii. Nos. 97-102. 1886. *Purchased.*

H. A. Nicholson and R. Etheridge, jun. On the Tasmanian and Australian Species of the Genus *Stenopora*, Lonsdale, 173.—H. A. Nicholson. On some new or imperfectly known Species of Stromatopora-roids, 225.—G. J. Hinde. *Hystriocrinus*, Hinde, versus *Arthroacantha*, Williams: a Question of Nomenclature, 271.—J. N. Woldrich. On the Question of the Origin of the European Races of Dogs, 295.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca: No. XX. On the Genus *Beyrichia* and some new Species, 337.—H. A. Nicholson and A. H. Foord. On a new Genus of Devonian Corals, with Descriptions of some Species of the same, 389, 518.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca: No. XXI. On some Silurian Genera and Species, 403.

- Athenæum (Journal). Nos. 3008–3036. 1885.
 —. Nos. 3037–3060. 1886.
 —. Parts 690–696. 1885.
 —. Parts 697–702. 1886.
- Ballaarat. School of Mines. Annual Report, 1886. 1886.
- Barnsley. Midland Institute of Mining, Civil, and Mechanical Engineers. Transactions. Vol. x. Parts 76–80. 1885 and 1886.
- Basel. Naturforschende Gesellschaft. Verhandlungen. Theil vii. Heft 3. 1885.
 —. Schweizerische paläontologische Gesellschaft. Abhandlungen. Vol. xii. 1885. 1885. *Purchased.*
 G. Maillard. Supplément à la Monographie des Purbeckien du Jura.
 —P. de Loriol. Premier supplément à l'échinologie helvétique.
- Bath. Natural-History and Antiquarian Field Club. Proceedings. Vol. vi. No. 1. 1886.
 J. McMurtrie. Notes on the Occurrence of Salt Springs in the Coal Measures of Radstock, 84.—H. H. Winwood. List of Fossil Mammalia found near Bath, 95.
- Belfast. Natural-History and Philosophical Society. Report and Proceedings for the Session 1884–85. 1885.
 —. Naturalists' Field Club. Annual Report and Proceedings. Ser. 2. Vol. ii. Part 5 (1884–85). 1886.
 Wm. Swanston. Lignites and Silicified Wood of Lough Neagh, 354.—H. W. Lett. Remains of Red Deer at Maralin, 378.—J. Wright. Cretaceous Foraminifera of Keady Hill, Appendix ix. No. 4.
- Berlin. Deutsche geologische Gesellschaft. Zeitschrift. Band xxxvii. Hefte 2–4. 1885.
 J. Walther. Die gesteinsbildenden Kalkalgen des Golfes von Neapel und die Entstehung structurloser Kalke, 329.—F. Hilgendorf. Die Steinheimer Gürtelchse *Propseudopus Fraasii*, 358.—J. Felix. Kritische Studien über die tertiäre Korallen-Fauna des Vicentins nebst Beschreibung einiger neuer Arten, 379.—W. Branco. Ueber einige neue Arten von *Graphularia* und über tertiäre Belemniten, 422.—G. Gurich. Ein neues Fossiles Holz aus der Kreide Armeniens nebst Bemerkungen über paläozoische Hölzer, 433.—A. Sauer. Mineralogische und petrographische Mittheilung aus dem sächsischen Erzgebirge, 441.—H. Eck. Das Lager des *Ceratites antecedens*, Beyr., im schwäbischen Muschelkalk, 466.—H. Sanner. Beiträge zur Geologie der Balkan-Halbinsel, 470.—Franz Toula. Ueber einige von Herrn H. Sanner im Sliven-Balkan gesammelte Fossilien, 519.—H. Kunisch. Ueber den Unterkiefer von *Mastodonsaurus silesiacus*, n. sp., 528.—A. Schenk. Ueber die geologische Verhältnisse von Angra Pequenna, 534.—J. Walther. Ueber geologische Beobachtungen im Golf von Neapel, 537.—F. Schmidt. Nachträgliche Mittheilungen über die Glacial- und Postglacialbildungen in Ebstland, 539.—E. Dathe. Ueber schlesische Culmpetrefacten, 542.—G. Württemberger. Ueber den oberen Jura der Landgrube bei Goslar, 559.—H. Kunisch. *Dactylolepis gogolinensis*, nov. gen., nov. spec., 588.—E. Holzapfel. Ueber die Fauna des Aachener Sandes und seine Äquiva-

lente, 595.—C. A. Tenne. Ueber Gesteine des Cerro de las Navajas (Messerberg) in Mexico, 610.—G. Reuter. Die Beyrichien der obersilurischen Diluvialgeschiebe Ostpreussens, 621.—A. Arzruni. Ueber einen Paragonit-Schiefer vom Ural, 680.—H. Credner. Die Stegocephalen aus den Rothliegenden des Plauen'schen Grundes bei Dresden, 694.—C. W. Schmidt. Die Liparite Islands in geologischer und petrographischer Beziehung, 737.—F. J. P. van Calker. Diluviales aus der Gegend von Neu-Amsterdam, 792.—T. Ebert. Ueber ein Kohlenvorkommen in westpreussischen Diluvium, 803.—G. Berendt. Das unterdiluviale Alter des Joachimsthal-Oberberger Geschiebewalles, 804.—R. Wagner. Ueber neuere Versteinerungsfund im Röth und Muschelkalk von Jena, 807.—H. Eck. *Trichasteropsis cilicia*, Quenst. sp., aus norddeutschen Muschelkalk, 817.—F. Winterfeld. Ueber quartäre Mustelidenreste Deutschlands, 826.—A. Arzruni. Untersuchung einiger granitischer Gesteine des Urals, 865.—F. Wahnschaffe. Mittheilungen über das Quartär am Nordrande des Harzes, 897.—E. Waldschmidt. Ueber die devonische Schichten der Gegend von Wildungen, 906.—F. Frech. Ueber das Kalkgerüst der Tetrakoralen, 928.—F. Frech. Nachtrag zur "Korallenfauna des Oberdevons in Deutschland," 946.—J. Lemberg. Zur Kenntniss der Bildung und Umbildung der Silicate, 959.—F. Zirkel. Ueber Gesteine des Cerro de las Navajas in Mexico, 1011.—A. Remelé. Bemerkungen über die geologische Stellung des Joachimsthal-Lieper Geschiebewalles, 1014.

Berlin. Deutsche geologische Gesellschaft. Zeitschrift. Band xxxviii. Heft 1. 1886.

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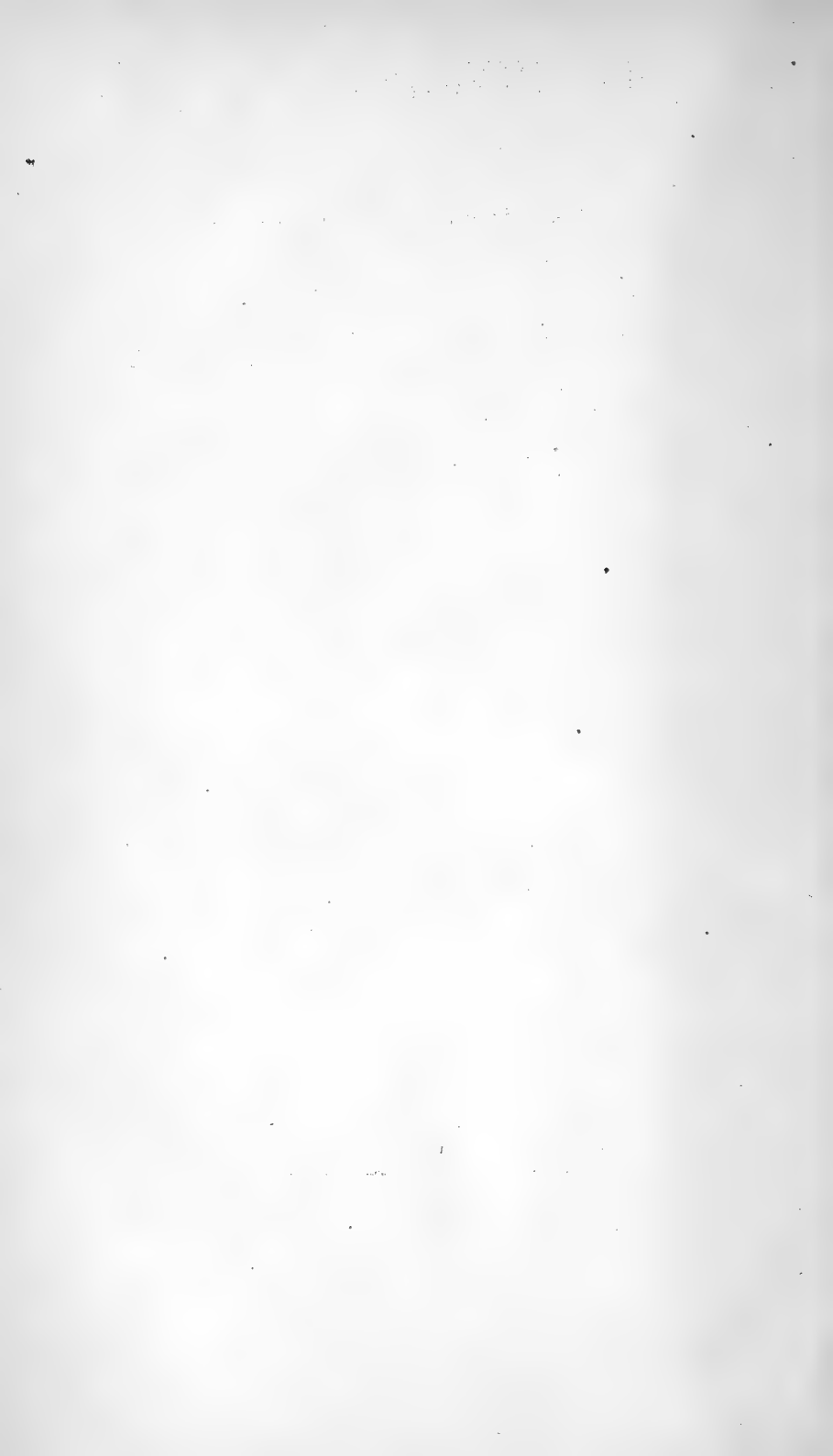
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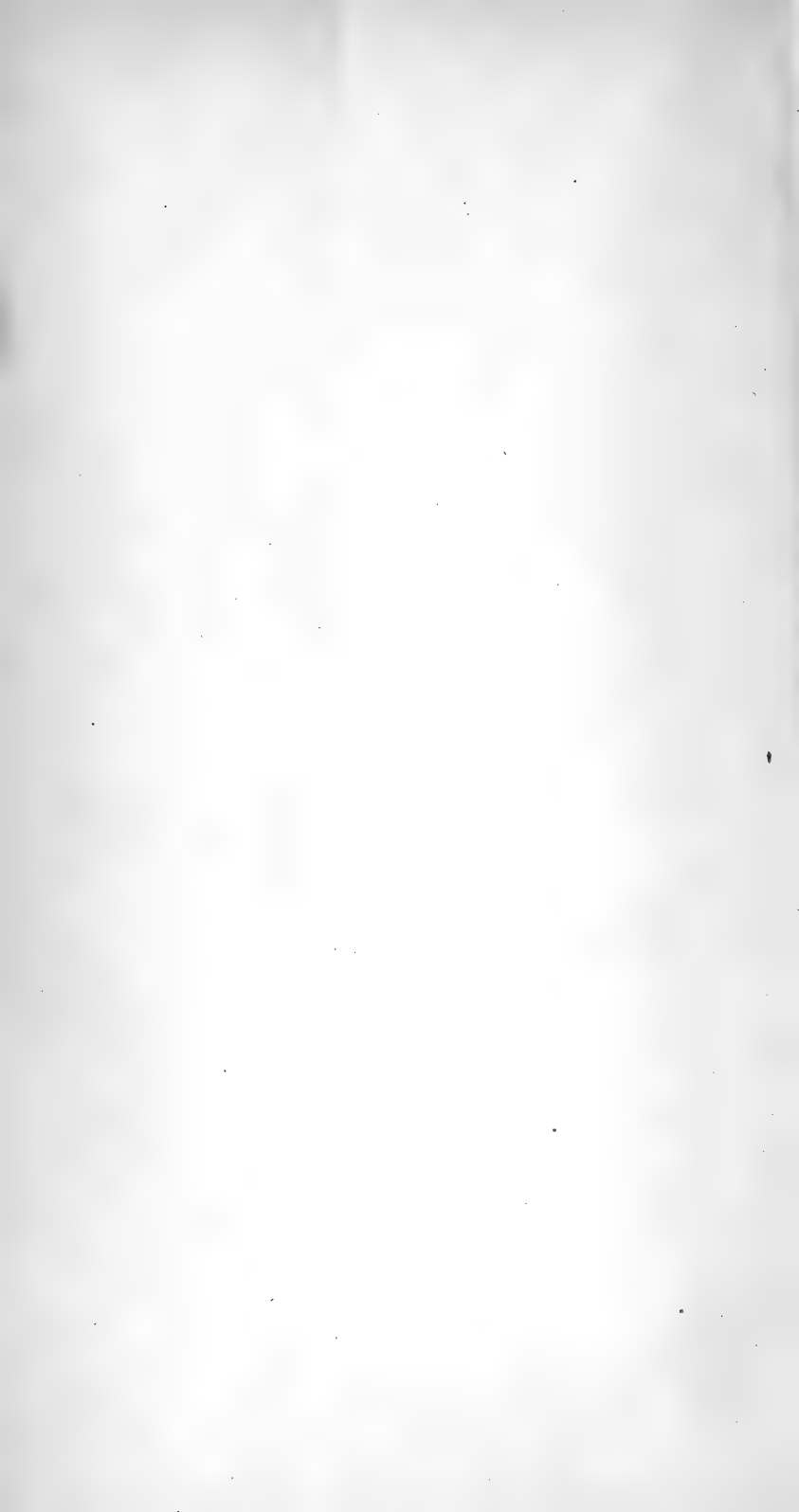
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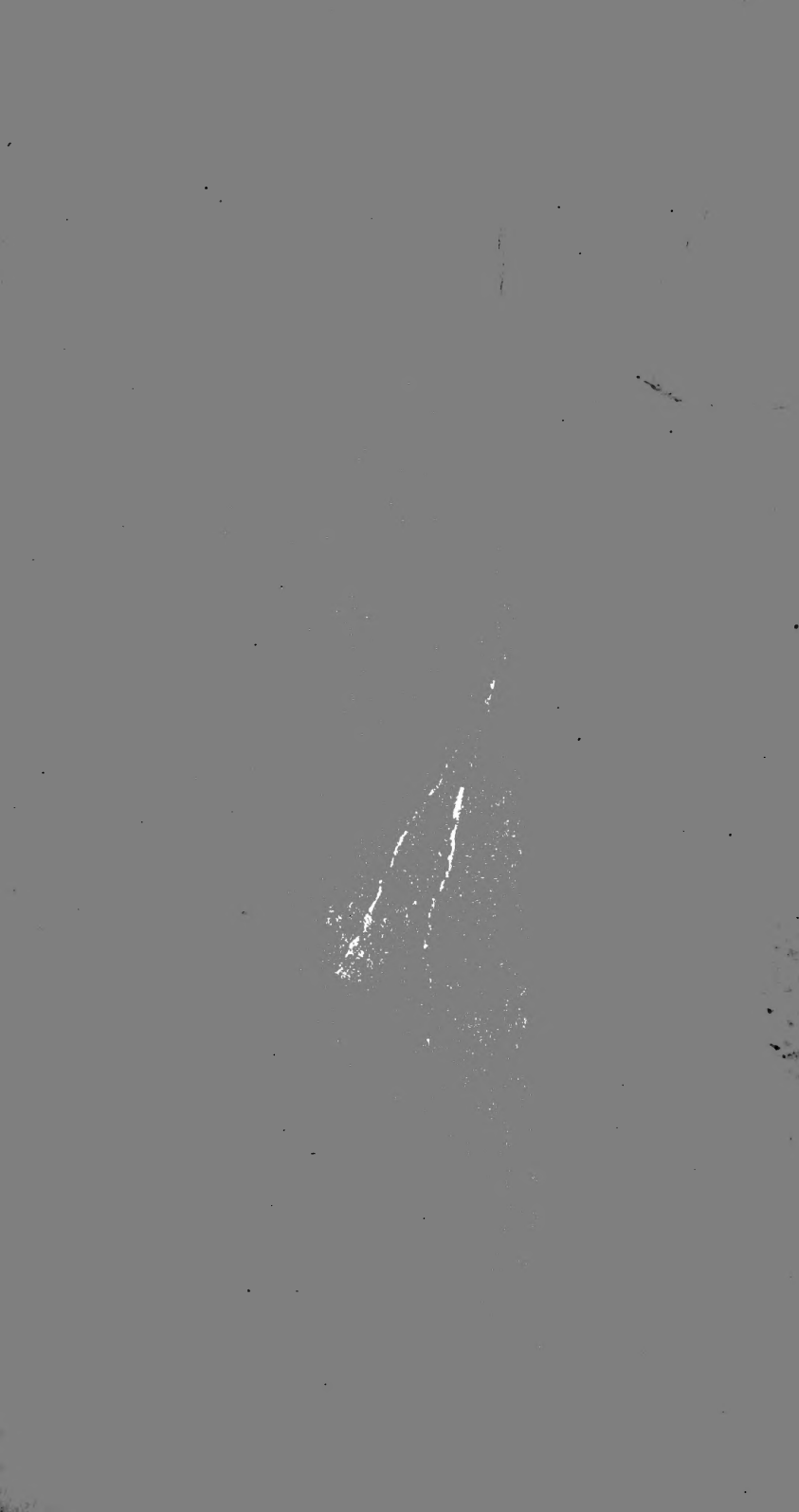
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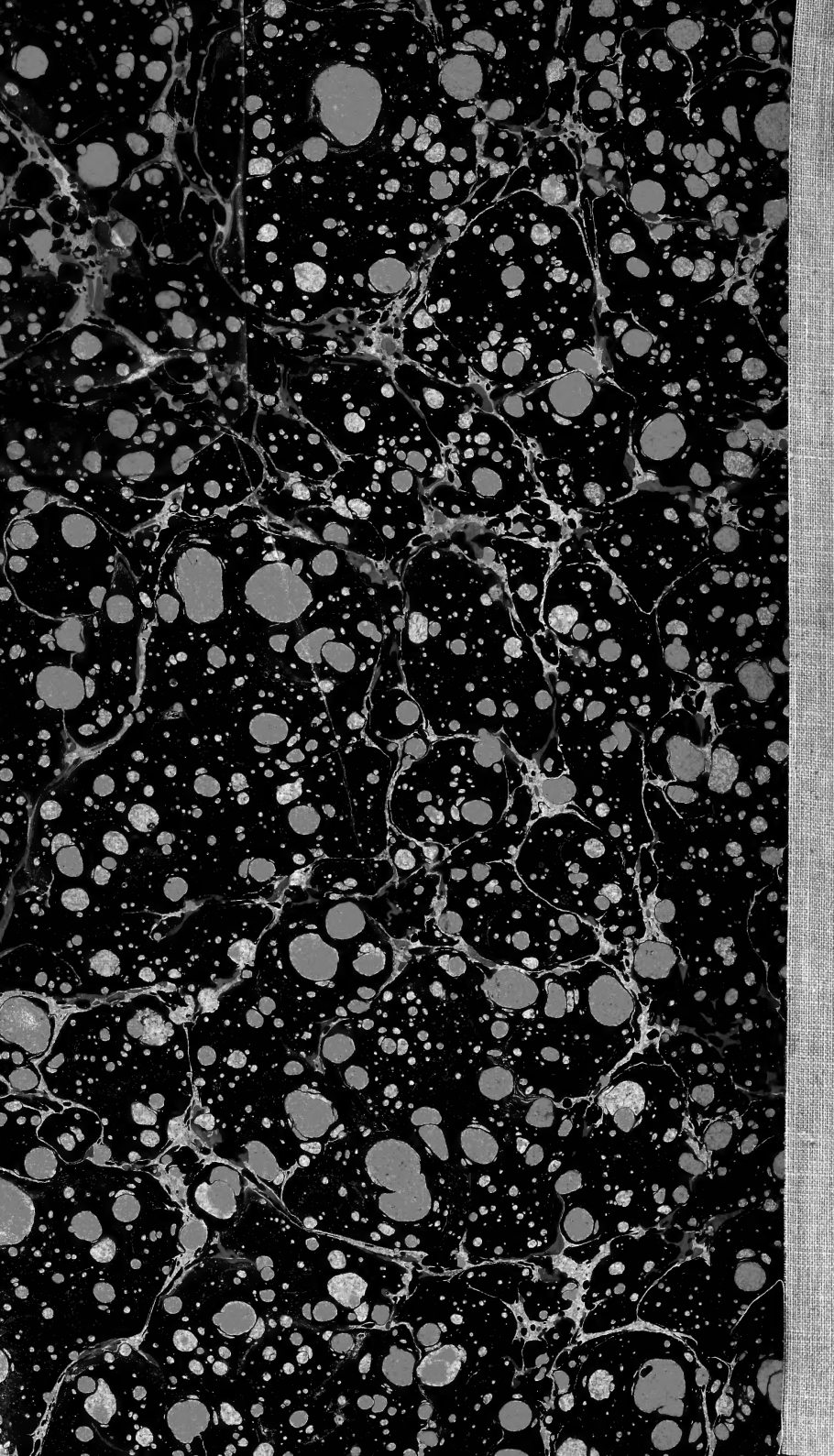
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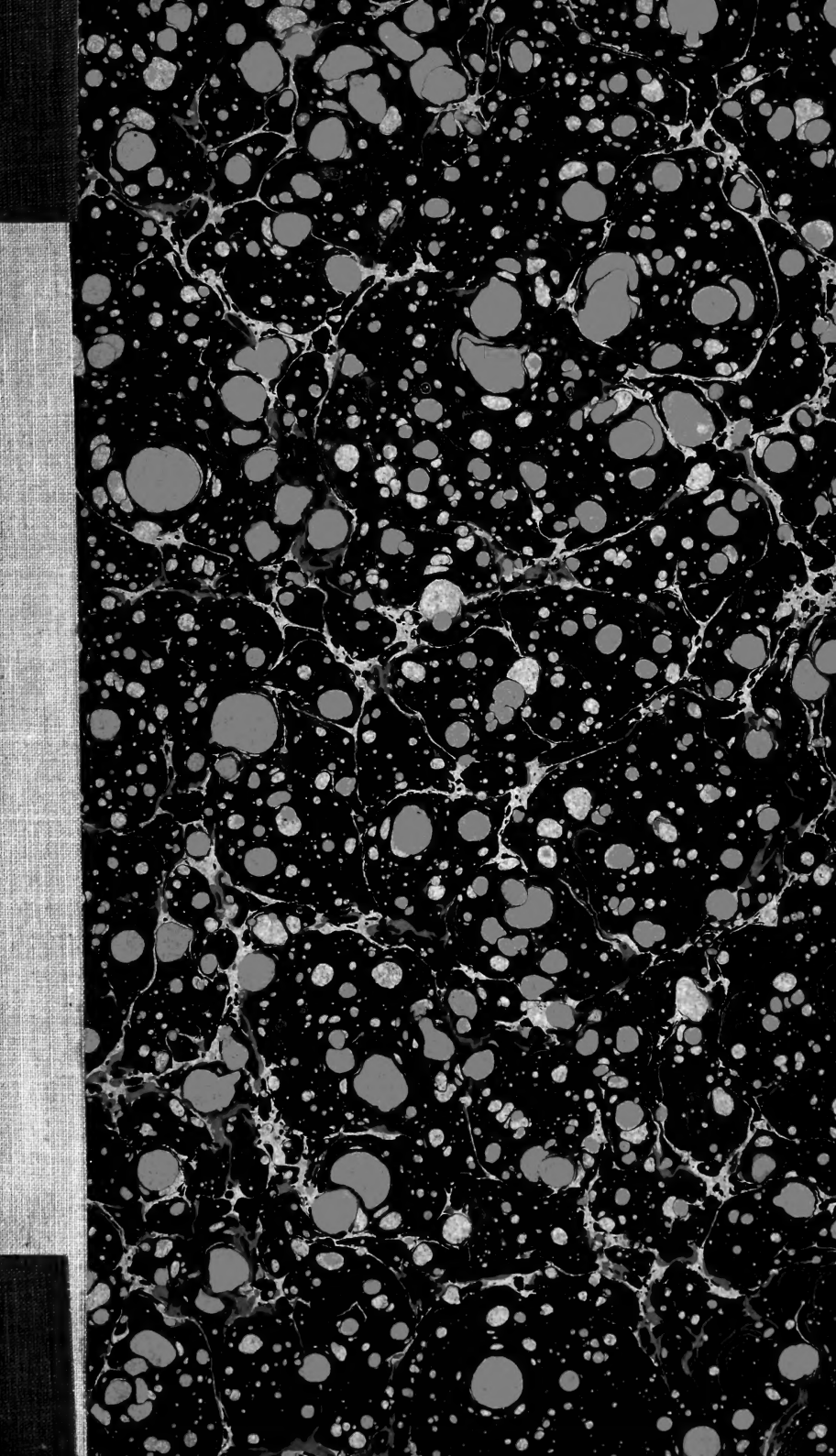
- Specimen of *Astrocania gibbosa*, from the Sutton Stone. *Presented by Prof. P. M. Duncan, F.R.S., F.G.S.*, in illustration of his paper read November 4, 1885.
- A collection of specimens and fossils, *presented by M. F. L. Cornet*, illustrating his paper "On the Phosphatic Beds in the Neighbourhood of Mons," read April 21st, 1886.











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