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JANUARY—DECEMBER, 1912.

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OR

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WITH WHICH IS INCORPORATED

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EDITED BY

HENRY WOODWARD, LL.D., F.R.S., F.G.S., F.R.M.S.

LATE OF THE BRITISH MUSEUM OF NATURAL HISTORY; PRESIDENT OF THE PALÆONTOGRAPHICAL SOCIETY; ETC., ETC.

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HORACE B. WOODWARD, F.R.S., F.G.S.

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NEW SERIES. DECADE V. VOL. IX.

No. I.—JANUARY, 1912.

ORIGINAL ARTICLES.

I.—Note on a Nepheline-Syenite Boulder dredged from the Atlantic.

By Lady Rachel Workman McRobert.

THROUGH the kindness of Dr. Flett there has come into my hands an interesting boulder of nepheline-syenite belonging to Sir John Murray, dredged during the expedition of the *Michael Sars* (1) from the Atlantic Rise at a depth of 1,750 fathoms at a place about 150 miles south-west of the south-western corner of Ireland (Station 95 of the Reports of the *Michael Sars* Expedition). The slices examined were slides Nos. F 2092 to F 2095 from the Geological Survey Collection and two belonging to Dr. Peach. It is a boulder of remarkable freshness, and so entirely unlike any other specimen as yet recorded from the floor of the Atlantic that the question of its origin is of some interest. The fact that no other fragments of the same type were obtained in this dredging militates against the view that it is part of a mass in situ on the sea-bottom. Its companions from the same station, and in fact all the specimens collected by the *Michael Sars*, have been recognized by Dr. Peach and Dr. Flett as similar to rocks occurring commonly in Ireland, the North-West Highlands, and the Southern Uplands of Scotland, and not one among them is closely related to the nepheline-syenite. Rocks of Irish types have also been described by Professor Cole and Mr. Crook (2) as a result of earlier dredgings of the Atlantic floor, and again no specimen has been found remotely resembling the subject of this paper. It would appear likely, then, that this syenite boulder is of foreign origin and that it has been transported by floating ice moving southwards—an interpretation suggested by Dr. Peach for most, if not all, of the associated rock-fragments, which it is important to note were found embedded end-on in the ooze and, probably owing to bottom currents, not entirely covered up by silt. This he inferred from the distribution of the adherent organisms still to be found on the stones. Perhaps this syenite is derived from an unknown outcrop on the west of Ireland or Scotland, or on the sea-bottom off there. The shape of the boulder unfortunately gives us no assistance in the question of its origin. It is an angular block 6 by 2 by $4\frac{1}{2}$ inches, shows no ice moulding, and has evidently been lying in the ooze near the surface. It is hoped that the description given below may some day lead to the identification of its source, although at present this important point must be left in doubt.

The specimen is fairly coarse in texture, distinctly heterogeneous, and is composed of two parts separated by a perfectly distinct line—a dark-grey portion with good needles of hornblende and abundant sphene, traversed by lighter veins composed mainly of felspar, nepheline, and sodalite, and a light-grey part in which ferro-magnesian minerals are quite subordinate, while twinned crystals of orthoclase are conspicuous and with a marked tendency to orientation along the line of separation. Under the microscope the rock shows a fairly coarse hypidiomorphic structure. The minerals are all very fresh, and there is practically no sign of incipient decomposition along the cleavage or margins. In the pale variety of the rock the minerals are the same as in the darker portion, and only vary in an increased proportion of felspar and nepheline, and in their orientation. These circumstances and the fact that the small pale veins traversing the rest of the rock are of similar type seem to indicate that this is the last consolidated portion of the magma.

The minerals in their order of importance are—

Potash-felspar, mainly perthitic orthoclase in good twin crystals, best developed in the pale variety; also in close association with nepheline, often enclosing it poecilitically.

Soda-felspar, albite showing its characteristic fine lamellar twinning, present in very small amount and more idiomorphic than the orthoclase; it occurs also in very fine perthitic intergrowth with orthoclase. Microcline is absent.

Nepheline in perfectly clear large plates or intergrown with felspar, often crowded with fluid inclusions and small grains of augite.

Sodalite, crowded with innumerable liquid inclusions and minute crystals of the basic minerals, and presenting a cloudy appearance, with occasional aggregate polarization. It fills up spaces left by the felspar and nepheline, and is allotriomorphic. Rounded patches are also enclosed by large plates of felspar, so that it must have started crystallizing simultaneously with the felspar and continued subsequently. It is pale blue in hand-specimen.

Hornblende, greenish brown and very pleochroic; $a = X =$ yellow or pale brown, $b = Y =$ dark brown, $c = Z =$ dark brown; very intense in good idiomorphic crystals, with an extinction angle of 17° or 18°. The crystals are grouped together in close association with the iron-ores, sphene, and ægirine-augite. It is the chief ferro-magnesian constituent, and is moulded around the other above-named constituents. With ægirine-augite it occurs in parallel intergrowth, and often forms the outer shell of crystals in which the kernel is the pyroxene.

Ægirine-augite, a pale-green variety and occasionally lilac, slightly pleochroic from lemon yellow to pale green, with an extinction angle of about 25° or 30° and quite subordinate to hornblende.

Sphene, in excellent double-wedged lozenges frequently twinned, of a curious pale yellow grey, with a pleochroism marked by variation of intensity rather than of colour. The margins are often corroded. Its inclusions are of apatite, felspar, nepheline, and even sodalite in some instances, thus further confirming the long period of crystallization of the latter.

Magnetite, in irregular grains and hexagonal crystals, containing inclusions of apatite, and generally surrounded by a green rim of pyroxene. In some instances it forms the nucleus of crystals of ægirine-augite, surrounded by hornblende. It is restricted to portions of the slide rich in these. Some of the iron-ore seems to be titaniferous, and in one instance shows alteration to leucoxene.

Apatite is abundantly scattered throughout all the minerals in small crystals, usually taking the form of elongated needles.

A consideration of these minerals and their association leads one to assign this specimen to the foyaite type; the percentage of potash-felspar is high and slightly exceeds that of the nepheline. The ferro-magnesian minerals are of minor importance, their chief constituent being an amphibole, so that this rock may be added to the comparatively restricted list of Amphibole Foyaites, and as yet none of these have been recorded from the Atlantic coasts.

In this basin some of the most noteworthy occurrences of nepheline-syenites are in the Sierra de Monchique (Portugal) (3), in the Langesundsfjord (Southern Norway) (4), at Julianchaab in Greenland (5), at Salem, Essex Co., Mass. (6), and Beemerville, N.Z., and in Assynt, Sutherland (7).

The specimen under consideration seems to have very little affinity with any of these. One essential difference from the rocks in Portugal, Norway, and Salem, Mass., is, that these are all pyroxene foyaites. The boulder further differs from them in the absence of biotite, and in the case of the last-named one, in the absence of zircon and eudialite. It shows none of the peculiar radial structure so marked in the pegmatite of Låven, Langesundsfjord, and of the harbour at Salem. The possibility of its migration from Greenland is minimized by the completely different character of the rocks from Julianchaab, described by Ussing, up to the present. He distinguishes three chief types—

(*a*) A sodalite - syenite, in which sodalite is embedded in tiny idiomorphic crystals in felspar, nepheline, eudialite, and ægirine alike.

(*b*) A foyaite type, coarse-grained and composed of eudialite, microcline, microperthite (in broad plates), nepheline, ægirine, arfvedsonite, and a little sodalite.

(*c*) A fine-grained variety with narrow felspar laths, acicular ægirine, and much iron.

The melanite-bearing rock from Loch Borolan is too well known to require description, and it is evident that the boulder in no way resembles it.

Conclusion.

The outstanding characteristics of the nepheline-syenite boulder here described are thus: its great freshness, the restricted number of its minerals and their normal habit, the prominence of hornblende, the complete absence of all rare minerals such as are so commonly found in nepheline-syenites, and the presence of a fair amount of iron-ore, although the rock is by no means very basic. It cannot at present be compared with any known syenite of the North Atlantic basin.

References to Literature.

(1) Hjort, J. "The *Michael Sars* North Atlantic Deep-sea Expedition, 1910": Geogr. Journ., xxxvii, 4, 5, 1911.

(2) Cole, G. A. J. & Crook, T. "On Rock-specimens dredged from the Floor of the Atlantic off the Coast of Ireland": Mem. Geol. Surv. Ireland.
(3) Weroeke, L. van. "Ueber den Nephelinsyenit der Serra de Monchique": N.T., 1880, ii.
(4) Brögger, W. C. "Die Eruptivgesteine des Kristianiagebiets," 1898.
(5) Ussing, N. V. "Mineralogisk petrografiske Undersögelser of Grönlandske Nefelinsyeniter": 1 og 2 del Meddeleser om Grönland, xiv, Kjöbenhavn, 1894.
(6) Washington, H. S. "Petrographic Province of Essex Co., Mass.": Journ. Geol. Chicago, 1899.
Sears, J. H. "On Occurrence of Augite and Nepheline Syenites, Essex Co.": Bull. Essex Inst., 1893, xxv.
(7) Horne, J. & Teall, J. J. H. "On Borolanite": Trans. Roy. Soc. Edinburgh, vol. xxxvii, pt. i, 1892.

II.—On a New Species of Mouse and other Rodent Remains from Crete.

By Dorothea M. A. Bate.

On looking over a small collection of rodent remains from the Pleistocene cave-deposits of Crete, Mr. Oldfield Thomas drew my attention to one specimen which appeared to be of special interest. It consists of an imperfect right mandibular ramus still in the matrix, and which contains the base of the incisor in a fragmentary condition, and the first and second molars in a perfect state of preservation. The third molar is missing. This specimen was obtained from a cave-deposit on the south side of the little bay of Sphinari[1] on the west coast of Crete. The deposit is almost totally destroyed and is still partially submerged; a few fragmentary remains of an ungulate were also observed and appeared to be those of the Cretan deer *Anaglochis cretensis* of Simonelli, which occurs in so many of the cave-deposits of the island.

It is always unfortunate when a new form is represented by one or two fragments, as in this case, for the scanty material available makes it impossible to speak with certainty of its closest affinities. The molars under discussion are typically murine in pattern and must have been those of a mouse of very large proportions, one which, so far as I am aware, has no equal in size in the Mediterranean region. It is therefore proposed that it should be known as *Mus catreus*, it being understood that the generic name is here used in its older and wider sense. The fact of an innominate bone of large size and presumably belonging to this species having been obtained from another cave-breccia in the island lends additional weight to the belief that it is not the remains of an individual 'sport' that are being dealt with, but that these more probably represent another instance of a giant form occurring among the smaller mammalian fauna of an island.

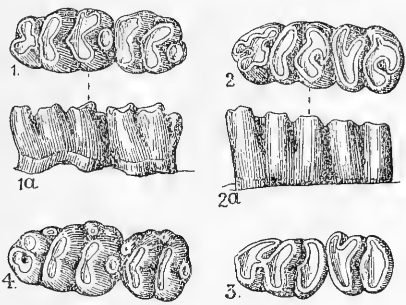
The two molars in the Cretan specimen are high-crowned and not very broad. They are not in an advanced stage of wear; the triturating surfaces of the parallel tubercles of both teeth have been worn to a common level, but the two anterior laminæ of the first tooth are barely connected to form the square cross of the typical Murine $m._{\overline{1}}$.

[1] "Pleistocene Mammalia in Crete": Geol. Mag., n.s., Dec. V, Vol. II, p. 197, May, 1905.

Both molars have well-developed supplementary cusps. With regard to the height of the crowns Mr. Hinton pointed out to me that in this they approach *Rhagamys orthodon* of the Pleistocene cave-deposits of Sardinia and Corsica, and at first sight the resemblance seemed to be sufficiently close to warrant their inclusion in that genus. However, there is perhaps hardly sufficient data at present to justify this, for, although the Cretan molars are decidedly high-crowned, it will be seen from the measurements given below that they are not more so than obtains in *Cricetomys*. Further, while m. $_{\overline{1}}$ in *M. catreus* is twice the antero-posterior length of the corresponding tooth in *R. orthodon*, the height of its crown is only one-third more. The following measurements, in millimetres, will give some idea of the comparative sizes of the Cretan mouse, *Epimys*, *Rhagamys*, and *Cricetomys*.

	E. rattus.	*E. decumanus.*	*R. orthodon.*	*M. catreus.*	*Cricetomys.*
Ant.-post. length of m.$_{\overline{1 \text{ and } 2}}$.	4·5	5·5	4·5	8	8·5
Ant.-post. length of m.$_{\overline{1}}$ . .	—	—	2·5	5	5
Greatest width of crown . . .	2	—	2	3	—

The width of crown in a worn specimen of *E. decumanus* is slightly more than 2 mm. In *Cricetomys* the complete series measures 11·5 mm. antero-posteriorly, while in *E. decumanus* and *E. rattus*



FIGS.
1, 1*a*. First and second right lower molars of *Mus catreus*, n.sp. 1, crown view; 1*a*, inner view. × 3.
2, 2*a*. *Rhagomys orthodon*, Hensel, sp. 2, crown view; 2*a*, inner view. × 5.
3. Ditto. Crown view of teeth in more advanced state of wear. × 5.
4. *Cricetomys*. Crown view. × 3.

this measurement is 7 mm. and barely 6 mm. respectively, and in a specimen of *R. orthodon* from Corsica 5·5 mm. The greatest height of the Cretan molars above the inner alveolar border is 3 mm. and is practically similar in *Cricetomys*, while in a Sardinian example of *R. orthodon* this is very slightly more than 2 mm.

From the above it is evident that the molars under discussion are those of a much larger animal than either *R. orthodon* or *E. decumanus*.

and that in fact it agrees in this respect with *Cricetomys*. In spite of the similarity in size the Cretan molars are at once distinguishable from those of *Cricetomys* by the presence in the latter of two extra tubercles on the outer border of both m. $_{\overline{1}}$ and m. $_{\overline{2}}$.

Although not very worn there is no sign in the Cretan specimen of the third anterior cusp in m. $_{\overline{1}}$ which seems to persist for a considerable time in the examples of *Rhagamys* from Sardinia and Corsica which I have examined. This extra anterior tubercle is given by Dr. Forsyth Major [1] as one of the characteristics of *R. orthodon*, in which it agrees with the group of mice including *Apodemus sylvaticus*, and differs from that containing *Epimys* and *Mus musculus*. The paired tubercles appear to be somewhat further apart in *M. catreus* than in *R. orthodon*.

A small piece of very hard breccia from another Cretan cave-deposit contains an imperfect left innominate bone believed to be that of the species to which belong the molars described above. The inner surface of the acetabular region is exposed, and, although only partially preserved, it is evident that it must have belonged to a Murine of considerably stouter proportions than *E. decumanus*. Further, the iliac crest springs from the ilium very close to its acetabular end, much more so than is the case in *E. decumanus*, and in this agreeing with *Cricetomys*, although the whole specimen is somewhat less robust than in the latter. *Cricetomys*, it will be remembered, is a recent genus distributed over the whole of inter-tropical Africa, but, so far as I am aware, has not been obtained in a fossil state.

Other rodent remains found in the Pleistocene cave-deposits of Crete include those of an *Acomys*, still found in the island, and also of *Epimys rattus*. This last is of more interest than might at first be supposed, not only as indicating coexistence with *Mus catreus*, but also because at the present day rats are found only in the towns and villages. In Cyprus a brown form of *E. rattus* is extremely common, both close to human habitations and in the country, and it is a significant fact that there is no weasel or stoat in that island. In Crete, on the other hand, a large weasel occurs,[2] consequently the finding of the fossil remains of a rat raises the question as to whether this rodent roamed over the island until its radius was checked and circumscribed by the comparatively late introduction of the weasel, by which it has been supplanted.

It may be of interest to note that one of the characteristics of the plentifully distributed Cretan field-mouse [3] of the present day is that in size it is inferior to other Mediterranean forms.

Remains of the *Myoxus* found by Spratt and identified by Falconer were not met with by me.

[1] "Rodents of W. Mediterranean": GEOL. MAG., N.S., Dec. V, Vol. II, p. 503, 1905.

[2] Proc. Zool. Soc., vol. ii, pp. 319–20, 1905.

[3] "*A. sylvaticus creticus*, Miller": Ann. Mag. Nat. Hist., ser. VIII, vol. vi, p. 460, November, 1910.

III.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from Decade V, Vol. VIII, p. 156, 1911.*)

(PLATE I.)

Discoflustrellaria Trimensis, sp. nov. (Pl. I, Figs. 1–3.)

Zoarium small, highly conical, slightly compressed in one direction, very fragile.

Zoœcia rather bluntly hexagonal, subradially arranged in straight rows which from time to time diverge to admit a new row, length ·35–·4 mm., width about the same; the area varies from distinctly elliptical to practically circular; maximum length ·33 mm., breadth ·3 mm.

Oœcia apparently not uncommon, though delicate and rarely well preserved; they are strongly inflated, but nearly rectangular in plan, with the free edge straight (when perfect); they roof in the upper end of the zoœcia, which is of abnormal length, and remain conspicuous by their length when the oœcia have been destroyed; they tend to encroach slightly on the area of the succeeding zoœcium.

Avicularia of the hour-glass type, closely resembling those of *Membranipora anguiformis* (*ante*, April, 1910), but with the upper part of the hour-glass larger than the lower and with indications of a slender bar crossing the lower end of the neck of the hour-glass similar to those shown by *Membranipora sagittaria* (*ante*, April, 1910). They seem to be confined to the beginning of new rows of zoœcia.

The species occurs very rarely at Trimingham, and but for the single specimen shown in Fig. 1, which is perfectly discoidal, though as a cone it has lost its apex, I should not have ventured to publish the opinion I had formed from fragments that it was a *Discoflustrellaria*. The species is easily distinguishable by its avicularia (the 'cellules avortées' of the generic diagnosis).

Lateroflustrellaria robusta, sp. nov. (Pl. I, Figs. 4–10.)

Zoarium strong, typically conical, but varying in height from 3 to 5 mm.; the high specimens are generally rather elliptical, the low ones are generally circular.

Zoœcia symmetrically hexagonal; the initial (and central) zoœcium is quite abnormal, being larger than the others and shaped like an elliptical funnel, at the bottom of which is a long and narrow triangular aperture with a stout and blunt projection from each side; over the base of the triangle and hiding the greater part of it there hangs a short, broad, rounded projection at a level a little below the rim of the funnel; round the initial zoœcium there is a ring of zoœcia of approximately normal size and shape, but retaining modifications of the stout internal projection of the initial zoœcium, which often simulate a front wall of ordinary Escharine type; outside this ring the zoœcia (except for the first one or two of a row, which may be subtriangular) are all alike, appearing on the surface as a regular network of large, very slightly elliptical apertures with thin boundary walls, divided from one another by fine sutures, and curving downwards so that each passes under the preceding one; indications of paired round pores in the end wall some way below the surface-level are seen from time to time; length about ·52 mm., breadth about ·48 mm, diameter of aperture about ·4 mm.

Oœcia short low and wide hoods occurring only near the outer margin of mature zoaria, and so inconspicuous that they can only be distinguished with certainty from slightly projecting zoœcial walls by looking horizontally along the zoarial surface.

Basal lamina smooth, divided by more or less radiating sutures into lines corresponding with the real (but not the apparent) distribution of the zoœcia on the upper surface; the outlines of the individual zoœcia are almost always quite obliterated; the method of growth leaves a very characteristic impress at the edge of the zoarium, by which the nature of quite small fragments may often be recognized; pores occur irregularly in the lamina and are probably connected with the internal pores above mentioned.

Not uncommon at Trimingham, and owing to its robustness often well preserved. By the initial stages and the presence of oœcia it is easily distinguished from the only other Cretaceous *Lateroflustrellaria.*

EXPLANATION OF PLATE I.

(Figs. 1–4 from photographs by the author, Figs. 5–10 from drawings by Miss G. M. Woodward.)

FIG. 1. *Discoflustrellaria Trimensis.* A specimen, natural size.
,, 2. Ditto. A fragment of another specimen. × 12.
,, 3. Ditto. Ditto.
,, 4. *Lateroflustrellaria robusta.* A specimen, natural size.
,, 5. Ditto. The greater part of a very flat specimen, showing the parallel rows of zoœcia continuous past the central (initial) zoœcium. × 8.
,, 6. Ditto. The initial zoœcium and surrounding zoœcium from the specimen shown in Fig. 5. × 12.
,, 7. Ditto. Ditto, from another specimen. × 12.
,, 8. Ditto. Ditto.
,, 9. Ditto. Underside of another specimen. × 6.
,, 10. Ditto. Underside of and cross-section through another specimen, in which the individual zoœcia are still traceable. × 6.

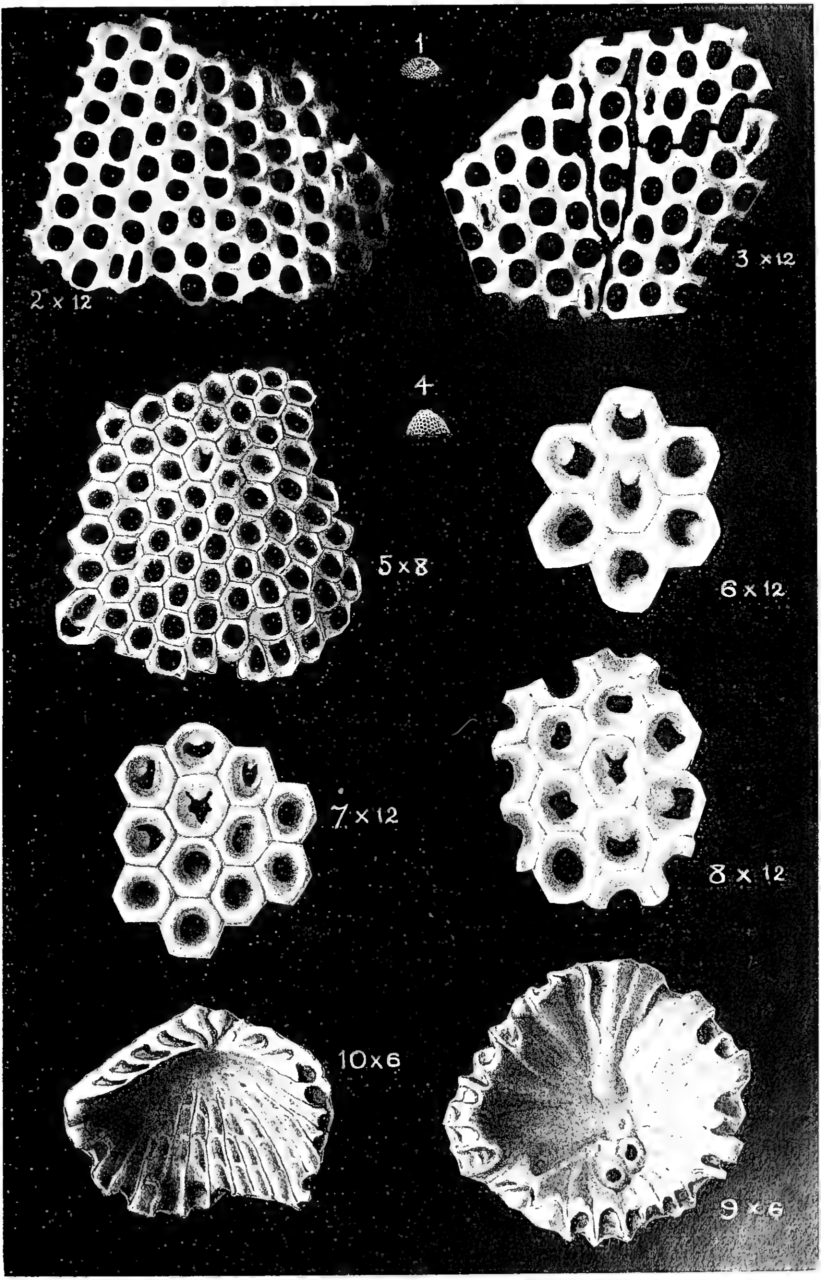
IV.—On the Evolution of the Apical System in the Holectypoida.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

(PLATE II.)

A. Introduction.

In two previous papers in this Magazine (Hawkins, 1910 and 1911) I have dealt with some features in the comparative anatomy of the ambulacral and interambulacral areas of the Holectypoida. The only other structure of the test for a comparative study of which sufficient material is available is the apical system. The present paper deals with this structure. I intend to summarize the results



Bemrose, Collo.

Chalk Polyzoa.

of my researches in a scheme for the classification and evolution of the group in a paper already partly prepared.

B. The points to be examined.

The apical cycles of plates are of fundamental importance in an Echinoid. Not only are they directly associated with the reproductive system, the water-vascular system, and some of the more delicate of the sensory organs of the animal, but it is from their outer margins that all the new coronal plates arise. The differences of structure which are shown in the apical system in various groups must therefore be indications of essential differences in the structure and development of both the skeletal and softer tissues of the body. From the foregoing sentences it will be realized that I differ considerably from the opinions expressed by Duncan (1889), and tend to regard the apical system as a phylogenetic index of the first importance. Nevertheless, I do not absolutely follow Pomel (1883) in treating the structure as the *chief* or only guide in classification.

Many careful studies of the apical system of Echinoids have been made, and the contrasts in its structure figure largely in the diagnoses of the larger and smaller groups. Many of the investigations were undertaken as a result of the brilliant, though apparently mistaken, attempt of P. H. Carpenter to homologize the apical cycles of Echinoids with the calycal cycles of Crinoids. The *Études* of Lovén (1875) contain perhaps the most important contributions to a comparative study of the structure from this standpoint that have been comprised in a single work.

Within the limits of one group of Echinoids there are usually not sufficiently marked differences of structure to render worth while the publication of detailed descriptions of the apical system alone in allied genera and species. In the case of the Holectypoida, however, the changes in detail are so many and so striking that a comparison, between genera at least, seems to lead to important results. No more convincing proof of the intermediate position occupied by the group between the various Echinoid orders can be supplied than that which a study of the apical system affords. And conversely, it is because the Holectypoida are an annectant group that the various forms show such a plasticity of structural development.

Almost the only reliable distinction between the early Holectypoida and the primitive Diademoids lies in the position of the periproct. However excentric the anus may be, it is always enclosed within the boundaries of the apical system in the Regular Echinoids. In *Pygaster*, for the first time in Echinoid history (if we except the aberrant and somewhat problematical 'Acyclic' Silurian forms), the periproct passes backwards to lie outside the cycles of the genital and ocular plates. Thanks largely to the work of A. Agassiz and S. Lovén, we now know that many, probably all, of the Irregulares, even of the Spatangoids, pass through a 'Regular' (though often *functionally* aproctous) stage in the course of their ontogeny. This means that the primitive apical system must, in every individual, be ruptured for the retrogression of the anus. Another result is that, even if the system regains its original quinqueradial symmetry, it will have to become a compact group of plates instead of a hollow ring enclosing a membrane-covered space.

There are thus two features in which the evolution of the apical system of the primitive Irregular Echinoids may be profitably traced. The first is *the recovery of the complete cycle* of plates, and the second the method of *the infilling of the centre* of the system.

Discussions and brief descriptions of the structure of the apical system in typical genera will now be given, and subsequently the stages in its evolution will be summarized.

C. The Apical System of *Pygaster*.

As far as the characters of this structure are concerned, the species of *Pygaster* fall into two well-marked groups. These groups correspond to the divisions named by Pomel (1883) '*Plesiechinus*'[1] and *Pygaster* [*sens. str.*]. The differences in the apex are due to the different shape of the periproct in the two divisions. In the '*Plesiechinus*' section the periproct has its greatest width in the adapical portion, while in *Pygaster*, *sens. str.*, the upper part is narrow, and the greatest width of the periproct is about midway between the apex and the margin of the test. '*Plesiechinus*' comes first both in stratigraphical occurrence and in phylogenetic order. *P. macrostoma* (Wright) is the only species of the group in which the apical system seems to be known. This species was suspected by Wright himself (1860) to be only a variety of *Pygaster* '(*Plesiechinus*)' *semisulcatus*, and it may at least be taken that the apical structures were similar in both forms. '*Plesiechinus*' may be said to contain those species in which the periproct has only just broken through the apical system, or even is in the act of breaking through. In *Pygaster*, *sens. str.*, it has, for the most part, receded from the apex, and the sides of the interambulacrum are closing in to heal the gash caused by its passage. *Pileus* marks the complete accomplishment of this process.

1. '*Plesiechinus*' (Pl. II, Fig. 1). In the Supplement to his Monograph, Wright (1860) figures the apical system of a small individual of *P.* '(*Plesiechinus*)' *macrostoma* (pl. xli, fig. 5*b*, by error termed *megastoma* in the legend). The drawing (copied in Pl. II, Fig. 1, of this paper) shows the apical plates to be arranged around the upper edge of the very large periproct and to form a smooth, apparently complete, margin to the aperture. Only four *genitals* are present, arranged in an almost linear manner transversely to the diameter of the test. Of the five *oculars*, the three anterior plates are normally situated in the angles of the genitals, while the two posterior plates rest against the posterior margins of the two postero-lateral genitals. In view of the fact that the posterior margin of the system is regular, with no considerable re-entrant angles, and that the posterior oculars do not reach to the periproct margin, it seems

[1] This name is systematically indefensible, being synonymous with Agassiz's *Pygaster*, whose type is *P. semisulcatus*. I use it in inverted commas here to avoid systematic discussions in a morphological paper.

certain that the fifth (posterior) genital did not exist. At most it may have been represented by one or more small plates situated on the anal membrane, and not necessarily distinguishable from the other anal plates. We find, then, that the first effect of the shifting of the periproct was the actual destruction of the odd genital plate, and the spreading out of the rest of the system into a transverse line of plates. The *madreporic genital* is larger than its fellows, but not very much so, and, as the whole system is not a cycle, it cannot be said to intrude at all into the centre of the apical system.

In '*Plesiechinus*', then, the system is absolutely ruptured, with no attempt at repair, while there is equally no trace of any infilling of the central part of the 'disc'.

2 *Pygaster, sens. str.* The apical system is well known in *P. umbrella*, *P. dilatatus*, and *P. macrocyphus*. Cotteau (1874) figures the system in all three species, and I have a specimen of *P. umbrella* in my collection in which most of the plates are well preserved. In this group, owing to the closing in of the upper part of the interambulacrum upon the adapical portion of the periproct, it is possible for the apical system to begin to reassume its cyclic character. In the work just referred to Cotteau seems to assert the presence of five *perforated* genitals in the genus, but this is certainly a mistake. (His figures give no support to his assertion.) Pomel (1883) is nearer the truth in his statement that the place of the fifth genital is taken by several small plates. I have not seen any specimens or figures which show any such plates preserved, but, judging from the facets on the posterior margins of the plates in my specimen, it seems certain that *at least one* plate occupied the position of the posterior genital. This will have been a roughly pentagonal plate (marked A in Pl. II, Fig. 2), in contact with the madreporic genital and the right posterior ocular, situated somewhat to the right of the antero-posterior axis of the system. To complete the symmetrical outline of the system it is necessary to postulate the presence of one or more smaller plates besides this one. Their probable positions are indicated in Pl. II, Fig. 2, by dotted lines.

The most striking feature of the apical system in this group is the enormous size of the *madreporic genital*. Not merely is it wider and more convex superficially than the other genital plates, but it extends inwards and posteriorly through the system, entirely separating the other genitals from one another, and monopolizing all the central space. In fact, the madreporite occupies just the position which, in a Regular Echinoid, would contain the anus and its membrane. The genital pores are relatively small, and each is encircled by a prominent raised rim. The *ocular plates* are small, and are rendered the less conspicuous by their depression below the general surface-level of the surrounding plates. They slope away from the centre, so that the ocular pore opens in a considerable hollow. After the pore is passed, however, the surface of the plate rises sharply to meet the proximal coronal plates.

Judging by Cotteau's figures of the apical system of *P. truncatus*, it would seem that in that species (the type of Pomel's third 'genus'

Macropygus) the structure is similar to that obtaining in *P. umbrella*. Indeed, it is natural that this should be the case, for the shape of the periproct is similar in both forms.

Pygaster, *sens. str.*, and *Macropygus* show an attempt to reconstruct the cycle of the genitals by the development of one or more plates in the posterior part of the system, while the centre of the system is filled up by the intrusion and expansion of the madreporite.

D. The Apical System of *Anorthopygus*. (Pl. II, Figs. 3, 4.)

Although contrary to the true stratigraphic sequence, it seems best to discuss this genus directly after *Pygaster*, as its apical system has more pronounced affinities with the *Pygaster* type than with that of its associates in the Lower Cretaceous. In all but the tuberculation and the position of the periproct it is a *Pygaster*, and was classed as such long after its specific recognition.

Cotteau (1859 and 1861) gives good figures of the apical system in both species of the genus. There are several siliceous moulds of *A. orbicularis*, from the Haldon Hill drift, in the British Museum, and they serve to verify the drawings taken from Continental specimens.

The system is a complete cycle, and, as far as its outline is concerned, is almost radially symmetrical. In spite of this appearance it is in reality of quite unsymmetrical structure. There are only four *genital plates*, the posterior one being absent. Three of the remaining plates are of uniform size, but the madreporic plate is so extended as to render the system actually ethmolysian. In *A. orbicularis* (Pl. II, Fig. 4) this large development of the right anterior genital is not carried out at the expense of the size of its fellows, as it is in *Pygaster*, for it is very little wider than the other three genitals. The posterior part of the plate has the outline of a perfectly normal fifth genital, and appears sharply marked off from the central (madreporiform) part of the plate. There is, however, no trace of a suture. The second species, *A. michelini* (Pl. II, Fig. 3), has, according to Cotteau, a much more *Pygaster*-like apical system. In it the madreporite is expanded transversely as well as posteriorly, and reduces the three other genitals to dimensions hardly greater than those of the *oculars*. These last are all five similar in form and size.

A feature of the system in *A. orbicularis* that appears in the moulds is the unequal thicknesses of the plates. The impressions of the oculars, and of the left anterior genital, are all shallow—in fact, at the same level as those of the coronal plates. But the other three genitals (the two postero-lateral and the madreporic plates) have left very much deeper scars on the mould, indicating their greater thickness. All the five specimens I have seen agree in this point, which, although of unknown significance, seems worth noting from its persistent occurrence.

In *Anorthopygus*, then, the cycle of the apical system is complete in form, but the posterior genital is missing, and the centre of the system is filled by the madreporite.

E. The Apical System of *Holectypus.*

As was the case in *Pygaster*, this genus is capable of division into two clearly defined groups on the structure of the apical system. These groups were named by Pomel (1883) *Holectypus* [*sens. str.*] and *Cœnholectypus*. Stratigraphically they are restricted to Jurassic and Cretaceous forms respectively. '*Holectypus*' has only four genital pores, while '*Cœnholectypus*' has five. This is not, perhaps, such an important distinction as some authors have considered, but, in view of the stratigraphic value of the distinction in this case, I think that Pomel's name *Cœnholectypus*, clumsy though it is, should be given at least a subgeneric sense for Cretaceous *Holectypi*.

1. *Holectypus, sens. str.* (Pl. II, Fig. 5.)

The most striking feature of the apical system in the Jurassic forms is the extreme prominence of the madreporite. This is central in position and dome-shaped. In *H. depressus* its prominence is perhaps more noticeable than in other species, but in *H. hemisphæricus* (where the whole system is not infrequently sunk below the level of the corona) it is still well marked. The water pores are, as usual, entirely restricted to the right anterior genital, which is therefore, as in *Pygaster, sens. str.*, very largely developed in its central extension. The full complement of five *genital plates* is present, and the posterior one, although imperforate, is often quite as large as the other three (ordinary) plates. The central development of the madreporite is so great that the *oculars*, no less than the genitals, are all in contact with it. In *H. depressus*, indeed, the oculars are almost of the same size as the genitals.

2. *Cœnholectypus.* (Pl. II, Fig. 6.)

The only constant difference in the apical system between this group and the last is in the perforation of the fifth genital. The size and position of the madreporite are similar in both divisions.

In *Holectypus, sens. lat.*, then, we see a complete recovery of the apical cycle in shape and in composition, and the monopolization of the centre of the system by the madreporite.

F. The Apical System of *Discoïdea.* (Pl. II, Fig. 7.)

In the case of *Discoïdea* there are two variable characters in the structure of the system which seem to be quite casual in their occurrence. Even Pomel was unable to found 'generic' distinctions upon them; and, indeed, they may differ in individuals of the same species. The two characters are: the presence or absence of a pore in the fifth genital, and the restriction of the madreporite to its normal plate, or its distribution over all five genitals. (The perforation of the posterior genital is usual, though not invariable.) The irregularity of development of such seemingly important features, within the limits of an otherwise circumscribed genus, would appear to indicate clearly the plasticity of structure which is generally associated with the rapid differentiation of new types. *Discoïdea*, as

I hope to show in a future paper, is near the parting of the ways between some important lines of evolution, and the unstable characters of its apical system are indices of that fact.

The cycles of plates are always complete, the *genitals* being usually tumid and considerably larger than the oculars. Whether the madreporite is in its usual plate, or scattered over all five, the right anterior genital is never much larger than the other four. All genitals take an equal share in the occupation of the centre of the system. This uniformity in size of the genitals confines the *oculars* to a marginal position in the system, and, owing to their relatively small size, they play quite an unimportant part in the construction of the apical disc.

In *Discoïdea*, then, the cycle is complete, and the centre of the system is occupied by equal extensions of all five genitals. The madreporite may, or may not, be central.

G. The Apical System of *Conulus*. (Pl. II, Fig. 8.)

There is a curious diversity of opinion as to the composition of the apical system in this genus. Wright and Cotteau both describe it as having five genital plates, the posterior one being small and imperforate. This small plate would, by its presence, serve to distinguish *Conulus* from *Pyrina* (see Pl. II, Fig. 9). In spite of the figures given by these authors I have been unable to find any trace of a fifth genital, although I have examined several hundreds of specimens of the common British species. Even in cases of marked abnormality no plate in the position of the posterior genital has been distinguishable. It seems unlikely, however, that both these authorities can have been mistaken, so that it is probable that some specimens (of both *C. subrotundus* and *C. albogalerus*) possess the posterior genital. I think it is safe to assume this character to be exceptional, and that the great majority of individuals have only the four genitals. I shall only describe and figure here the type that I have seen.

The apical system is not quite circular, but tends to be elongated along the antero-posterior axis. The tendency is, however, very slight. The four *genitals*, taken together, build a roughly square figure, into the middle of three of the faces of which the anterior oculars are inserted. The madreporic genital is considerably larger than the others, and occupies most, but not all, of the centre of the system. It never quite separates the two postero-lateral genitals. The madreporite is normally restricted to the right anterior plate. (There is a specimen of *C. albogalerus* in the collection of Mr. Ll. Treacher, F.G.S., which, in addition to other slight abnormalities, has the madreporite on all four of the genitals.) In the absence of the fifth genital the two posterior *oculars* meet along the median line, and are of much greater size than the other three. They are sometimes of about the size of the non-madreporic genitals, but are usually smaller.

Conulus, then, shows the cycle completed by the large development of the posterior oculars, while the centre of the system is largely, though not entirely, occupied by the madreporite.

H. The Trend of Evolution of the System.

It seems advisable to explain that the evolution indicated here is not necessarily coincident with the phylogeny of the group, but applies only to the lines of development of the one structure.

The passage of the periproct out of the apical system resulted at first in the complete destruction of the posterior genital and a displacement of the remaining plates into a transverse rather than a radiating series. This is the stage represented by the '*Plesiechinus*' section of *Pygaster* (Pl. II, Fig. 1). Subsequent stages may be divided into two series: first, those in which the posterior genital was permanently absent, and second, those in which it reappeared.

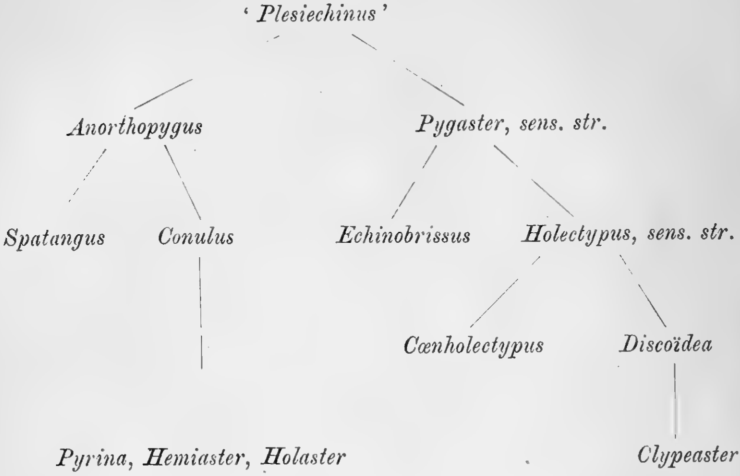
The simplest condition of the first series is exemplified by *Anorthopygus* (Pl. II, Figs. 3 and 4). Here, after the complete separation of the periproct from the apex, the madreporic genital passed back through the system, which therefore becomes ethmolysian. This condition results in an apical system hardly differing from that of a Spatangid, as may be seen by comparing Figs. 4 and 11 of Plate II.

By a slightly different process the two posterior oculars, instead of being widely separated by the intrusion of the madreporite, became enlarged and met one another across the posterior margin. The two postero-lateral genitals followed them, and later the two antero-lateral oculars. The various stages in the consequent thrusting forwards of the madreporite are indicated by a comparison of Figs. 4, 8, 9, 13 (Plate II), treating them as a sequence. *Conulus* is the only true Holectypoid that shows this condition typically. It is, however, a very general one among Irregular Echinoids, as its presence in such widely differing forms as *Pyrina*, *Hemiaster*, and *Holaster* shows (cf. Pl. II, Figs. 9, 10, and 13).

The second direction of development commenced with the *Pygaster*, *sens. str.*, group (Pl. II, Fig. 2), where the place of the fifth genital was occupied by one or more small plates distinct from those of the anal membrane. In some forms, notably among the *Echinobrissi*, the presence of more than one of these posterior plates became common, though not universal. The madreporite is large and tends to occupy all the centre of the system. In *Holectypus*, *sens. str.* (Pl. II, Fig. 5), the posterior genital became single and imperforate (a condition often present in *Discoïdea*), and finally, in *Cœnholectypus* (Pl. II, Fig. 6), it became perforated, thus rendering the apical system complete.

As a variant from this *Holectypus* plan, in which the madreporic genital was much larger than the other four, we find the *Discoïdea* principle, in which the posterior genital (whether perforated or not) was, in common with the others, of practically the same size as the madreporic plate. The most significant change in this group was, however, the spreading of the madreporic water-pores over all five genitals, accompanied by the reduction in importance of the oculars. The natural outcome of such a process was the apical system of the Clypeastroids (Pl. II, Fig. 12), where, apart from the fusion of the genitals, the structure was quite similar to that of *Discoïdea*.

Finally, using the generic names merely to indicate types of structure rather than true phylogenetic affinity, the tendencies of evolution of the apical system may be expressed in the following diagram :—



EXPLANATION OF PLATE II.

The figures are not drawn to a definite scale, and, except where otherwise stated, are generalized from several specimens.

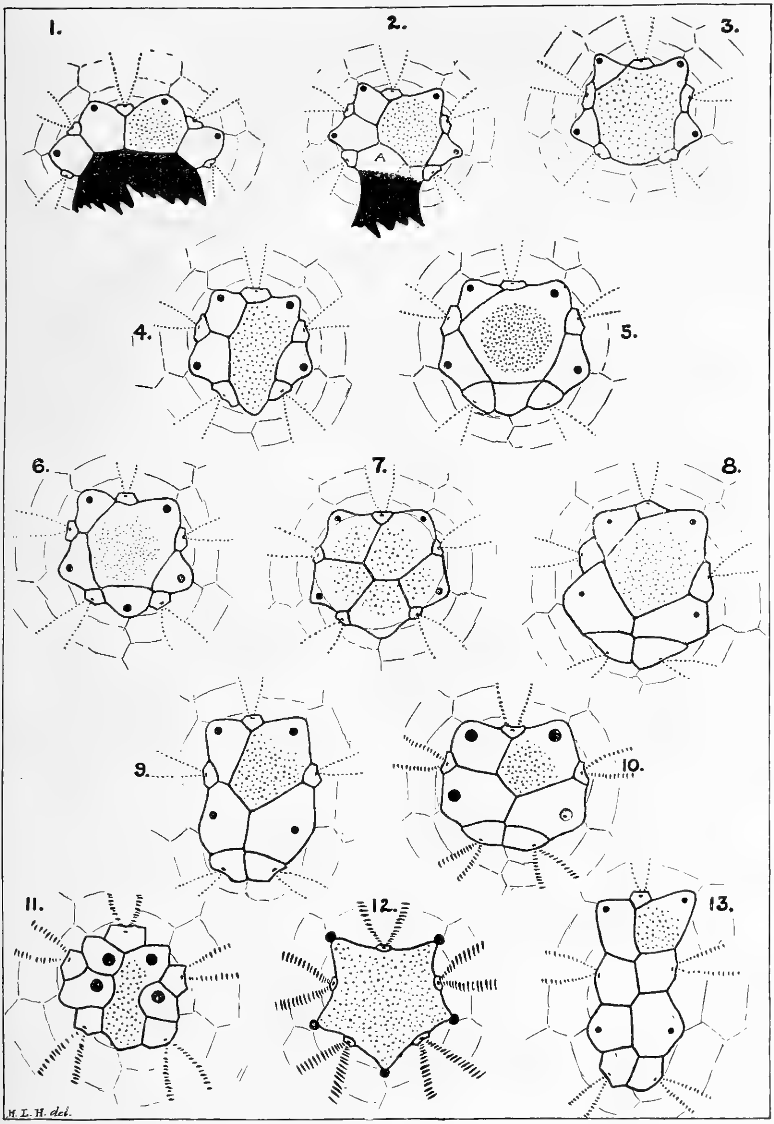
FIG. 1. Apical system of *Pygaster* ('*Plesiechinus*') *macrostoma* (after Wright).
,, 2. Apical system of *P.* ('*Pygaster*') *umbrella.*
,, 3. ,, ,, *Anorthopygus michelini* (after Cotteau).
,, 4. ,, ,, *A. orbicularis.*
,, 5. ,, ,, *Holectypus* (*Holectypus*) *depressus.*
,, 6. ,, ,, *H.* (*Cœnholectypus*) *cenomanensis* (after Cotteau).
,, 7. ,, ,, *Discoïdea cylindrica.*
,, 8. ,, ,, *Conulus albogalerus.*
,, 9. ,, ,, *Pyrina desmoulinsi.*
,, 10. ,, ,, *Hemiaster* or *Micraster.*
,, 11. ,, ,, *Spatangus.*
,, 12. ,, ,, *Clypeaster.*
,, 13. ,, ,, *Holaster* or *Echinocorys.*

V.—OUTLINES OF OILFIELD GEOLOGY.

By T. O. BOSWORTH, B.A., B.Sc., F.G.S.

INTRODUCTION.

IT is remarkable that in English geological literature and in our Universities so little attention is given to this important branch of geology. Probably it is because in this country petroleum occurs only in small quantity; nevertheless, in many parts of the British Empire petroleum mining has become a great and increasing industry, and is one of the chief directions in which geology is of practical



Apical Systems of some Irregular Echinoidea.

use to-day. The writer therefore hopes that an orderly summary of present knowledge may be useful.

Part I. Theoretical Considerations.

Origin.—Within a petroliferous formation as found to-day the oil is concentrated in certain positions in the most porous beds, whilst often the intervening rocks show little or no indication of oil. The origin of the petroleum has been much discussed, especially in American, Russian, and German literature.

The theories may be placed under two heads according to the supposed source of the carbon.

1. *Inorganic Origin.*—It is held that the oil has been introduced into the rocks from deep-seated sources in or beneath the earth's crust, where it was perhaps produced by chemical reactions between such substances as water, carbonates, carbides, carbon dioxide, etc., and some authorities maintain that the intrusion of hydrocarbons is one of the phenomena of vulcanicity, similar to the intrusion of igneous magma. For many reasons these theories have been rejected by the majority of 'oil-geologists', as they do not accord with the distribution of the petroleum.

2. *Organic Origin.*—It is held that the hydrocarbons have been produced by chemical changes in the organic matter present in the sediments. The organic origin is generally accepted, though there is much difference of opinion as to what animals or plants (terrestrial and marine) can give rise to petroleum and under what conditions.

The facts differ widely in different fields. In some the oil-rocks occur amidst thousands of feet of strata rich in marine fossils. In others they are amidst great thicknesses of shallow water, coastal or estuarine deposits, in which both animal and vegetable remains abound, e.g. Peru. Rich oil-sands are sometimes closely associated with coal-seams and lignites in formations where the organic matter apparently is mainly vegetable and terrestrial, e.g. in Assam. (Small quantities of oil have occasionally been met with in various British coal-fields.)[1] Again, in some fields the oil horizons are unfossiliferous sands separated and underlain by thousands of feet of clays and shales, most of which are entirely devoid of *visible* fossil remains, e.g. Trinidad.

In some fields the oil-rocks are associated with salt and gypsum, bearing formations from which the oil seems always to have originated, e.g. the Roumanian Oilfields. Yet again the oil-rocks occur in association with diatomaceous sediments. From such Dr. Ralf Arnold informs me there can be no doubt that much of the Californian oil has been derived.

It is supposed that the oil begins to form from the organic matter not long after deposition, as films and globules around and among the rock particles, accompanied by the salt water of sedimentation; but nothing definite is known as to the conditions of temperature and pressure necessary.

[1] Commercial quantities of oil from the Scottish Oilfield are not found present in the rocks as oil, but are produced on destructive distillation of certain carbonaceous shales.

With advancing age both temperature and pressure are increased owing to the deposition of sediments above, and at length the oil and salt water may be driven out and redistributed many times.

It is a remarkable fact, proved, in the Appalachian Oilfields at any rate, by innumerable deep borings, that as a rule the amount of water now present in the rocks decreases as depth increases. At great depths—several thousand feet—there is little or no moisture, even in porous sandstones, and the rocks are ready to absorb large quantities of water. At more moderate depths there is a little water and that is generally saline, whilst only at comparatively slight depths are the strata thoroughly invaded by fresh water from above. Generally, the further we explore a stratum down the dip the less is the volume and the greater the salinity of the water found.

How these rocks have lost their original water of sedimentation is not known, but perhaps it was expelled at a time when they were hotter or more compressed. All sedimentary rocks are to some extent porous, and at depths where they are thus dry, capillary action would exert a great influence on the movement of any fluid invading the strata or already imprisoned there. Capillary action has probably played an important part in the process by which the oil has been leached out of the beds of clay and shale.

The principal forces which have controlled the movements and ultimate position of the oil are—

1. *Vapour Tension* (*Gas Pressure*).—Commonly the pressure on the gas and oil is found to be far too great to be due to any hydrostatic pressure communicated to them, and it would seem that additional pressure has been and is being generated in situ. Such a change of vapour tension of the fluid may be brought about by chemical alteration still taking place. Similar changes in vapour pressure, due to chemical or thermal alterations, may have occurred often during the past history of the oil and have disturbed the equilibrium from time to time. The gas pressure, being equal in all directions, simply tends to force the oil out along any line of weakness.

2. *Capillary Action.*—This acts differentially among the strata and tends to produce motion in particular directions depending on the characters of the rocks. It is probably most effective at depth during the earlier history of the oil.

3. *Gravitation.*—In *dry* rocks gravitation imparts a downward motion to the oil, which seeks the lowest places in the containing stratum. In *wet* rocks gravitation tends to send oil upwards, for the fluids must arrange themselves in order of density—water at the bottom, oil resting on it, and gas occupying the space above. Where hydrocarbons are entrapped over water the water may impart a considerable hydrostatic pressure. The gravitation effects are the most important in determining the present position of the oil in most fields.

Under the action of these various forces the hydrocarbons have been leached out of clays and shales, and have undergone a very complicated history of movements, to and fro, through and among the rocks. A large amount of hydrocarbons is ever escaping into the atmosphere, whilst always considerable quantities remain temporarily entrapped.

Part II. The Accumulations of Petroleum.

Next will be given an epitome of the circumstances which are found to have been favourable to the accumulation of petroleum.

The chief rocks in which the entrapped oil finds accommodation are beds of uncemented sandstones and dolomitized limestone. Of these the oil sandstones are the more usual, but oil in dolomites is also common, e.g. in the Palæozoic oil-formation of the United States and Canada and in the Tertiary oil-rocks of Mexico. Other porous rocks occasionally contain oil, e.g. tuffs and much jointed shales.

Practical men have often classified the occurrences into two divisions—

Oil in anticlines.
Oil in monoclines.

The latter term has been used to include almost all cases where the oil strata are not now in the form of an arch (which was once thought to be essential). To geologists this is unsatisfactory, because the 'monocline' is so often simply one limb of a denuded anticline.

Here the accumulations will be classed in three main groups, according as they have been determined by—

A. Geological Structure.
B. Denudation Effects.
C. Petrographical Circumstances.

A. Oil Accumulations determined by Geological Structure.—Where the strata are not horizontal the geological structure has been the main factor in deciding the distribution of oil. Under the action of gravity oil tends to move upwards in wet rocks and downwards in dry rocks, and accumulation takes place wherever the geological structure provides an obstruction or a terminus to the path in which the oil is moving.

1. *Terrace Structure.*—Many varieties of this structure occur in the oilfields of Kentucky, East Ohio, Pennsylvania, New York, and West Virginia.

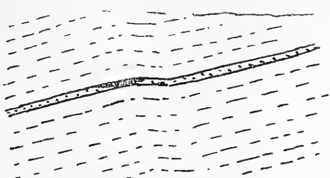


Fig. 1. Oil accumulation due to terrace structure. Sandstone, dotted; oil, black.

The strata have a prevalent slight dip in one general direction, but here and there the dip abruptly increases or decreases for a short distance and then continues as before. Often where these terraces are narrow and almost horizontal, accumulations of oil and gas are found. It would seem that the oil has been migrating in one direction—up the dip if the rocks contain water, or down the dip if they be dry—and that any sudden change in the inclination of the beds (especially a diminution) has acted as a slight check, causing local accumulation (Fig. 1).

2. *Undenuded Folds.*—In general, water, oil, and gas are all present in the porous oil-bed, and under the action of gravity arrange themselves vertically in order of density. Hence the gas will occupy the crests of anticlines, whilst the oil will be found in the limbs of the folds resting on the water, which will occupy the remaining space below (Fig. 2*a*).

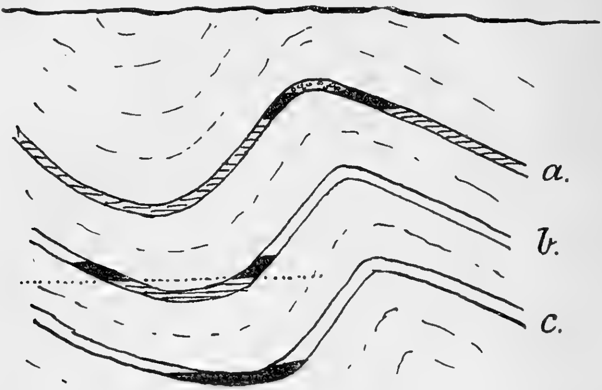


FIG. 2. Oil accumulated in undenuded folded beds. *a* = bed saturated with water; *b* = bed saturated with water up to a level shown by dotted line; *c* = bed containing no water. Oil shown black; gas under pressure shown by small circles; water shown by horizontal lines.

The heights of the oil will depend upon two factors: it will be in equilibrium under—

(1) The gas pressure generated—keeping it down.

(2) The hydrostatic pressure—keeping it up.

If there is no gas, oil will occupy the crest of the anticline. And if there is no water, oil will occupy the syncline. The wells must be placed accordingly.

A certain amount of *gas* is present in most fields, and in some cases there is such great quantity that it is exploited independently by wells on the anticlinal crests, as in some of the Pennsylvanian and West Virginian Fields and the Surakhany gas-field near Baku; often a single well will yield ten million cubic feet of gas per day, and when the well is closed a pressure of thirty to forty atmospheres may be registered. *Water* usually is present, and therefore the oil is found in quantity only at or near the crests of the folds. Sometimes, however, the porous rock contains only sufficient water to saturate it up to a certain level, in which case the oil is not forced so far up towards the crest whether there be much gas pressure or no (Fig. 2*b*). The Gordon sand in Pennsylvania is an instance.[1]

Oil in synclines is not common and rarely is present in commercial quantity, but occasionally in the absence of water considerable quantities have accumulated (Fig. 2*c*). Instances are cited in the Californian Fields.

The shapes of oil-bearing folds are very varied. Some are

[1] Bull. No. 318, U.S. Geol. Surv., 1907, p. 16.

symmetrical (e.g., Yenangyaung Oilfield, Burma), others have the axial plane inclined. In some fields, Trinidad for instance, the crests are sharp and narrow and may be only two or three miles apart, whilst in others they undulate so gently that the dip seldom exceeds a few degrees, and some oil-bearing folds are broad geo-anticlinals many miles across (in the United States).

Usually the anticlinal axis is not horizontal, but rises and falls repeatedly. This doming of the anticline causes such special concentration at the domes that sometimes the intervening parts of the anticline are barren.

When an anticline is asymmetrical the gentler slope generally provides the best well-sites, and gentle anticlines are usually more prolific than steep ones; indeed, many of the richest fields are on anticlines whose flanks slope at only a few degrees and whose crests are very broad. On very broad anticlinals, several miles across, the hydrocarbons are often concentrated in isolated pools where the circumstances are particularly favourable. Variation in porosity and bedding, faults, minor wrinkles on the fold, etc., have been important in determining these sites.

3. *Salt Domes* ('*Salines*'). — These remarkable structures are abundant in the oilfields of the Gulf Coastal Plane in Texas and Louisiana (Fig. 3). Sometimes the domes are of such recent elevation that they show as circular hillocks at the surface, hundreds or thousands of acres in extent, and upwards of 100 feet in height.

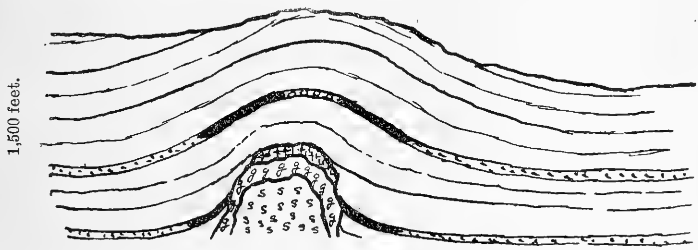


FIG. 3. Oil accumulation caused by a salt dome. Salt intrusion, *sss*; gypsum intrusion, *ggg*; dolomite intrusion, †††; sandstone bed, dotted; oil, black; gas shown by circles.

At depth beneath the upraised strata is found a great plug of crystalline salts which in some cases has burst right through the strata and reached the surface. The chief salts are sodium chloride, gypsum, and dolomite, which occur in ascending order. It is supposed that these have been precipitated from hot saturated solutions circulating below, and that the domes have been raised by the force of crystallization.

The domes apparently occur at places of weakness, such as the intersection of faults. Porous sandstones in such domed Tertiary strata form ideal sites for the accumulation of oil, and have yielded great quantities.

4. *Strata upraised by Igneous Intrusions.*—Probably this case is more common than is yet proved, for many domes and anticlinals may at depth be underlain by laccolitic or other intrusions (though if this

be so it would still be difficult to discriminate between the fold and the intrusion as to cause and effect).

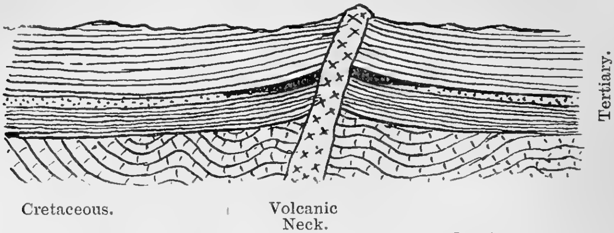


FIG. 4. Oil accumulation due to igneous doming.

In Mexico there are numerous volcanic necks which have burst through Tertiary strata, raising them and producing a dome-like structure around each core of igneous rock, and thus forming very favourable conditions for the concentration of oil in the sands (Fig. 4).

5. *Inclined Strata intersected by Dykes.*—In the same area dykes intersect the strata and sometimes act as dams to the oil ascending an inclined sandstone bed (Fig. 5).

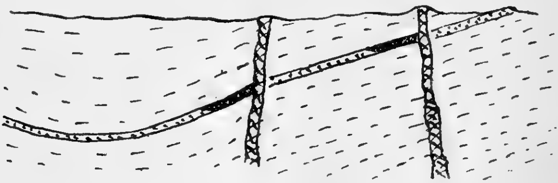


FIG. 5. Oil accumulation in a sand where dammed by dykes.

6. *Fault-sealed Oil-rock.* — Often oil ascending along an inclined porous bed is prevented from escaping at the surface by a fault which has displaced the outcropping portion and substituted impervious clays (Fig. 6).

FIG. 6. Oil accumulation in porous beds dammed by a fault.

Sometimes a whole row of wells has been placed alongside such a fault. A notable example is the Western Coalinga Oilfield, Los Angeles, California, but the case is quite common in many fields in combination with other structures, and many a big well may owe its success to the sealing effect of a small fault.

7. *Porous Strata Thrust over a folded Oil-generating Formation.*—This important class includes a variety of complicated structures, from some of which great quantities of oil have been obtained. The circumstances belong to regions of intense folding, and are best illustrated by the oilfields of Roumania, where they are well known.

In Roumania the source of oil appears to be the saliferous formation, and the places where the oil is concentrated lie along important lines of thrust-folding—"places where there has been maximum pressure and minimum resistance."[1] Along these lines occur very 'pinched' anticlines and overfolds with much overriding of one formation upon another. The saliferous formation contains hard massive salt rock and often forms the core of the fold, in which case oil is generally found.

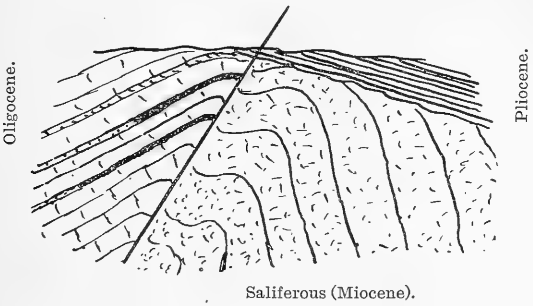


FIG. 7. Oilfield at Bushterrari. Oil derived from upfolded saliferous Miocene, but accumulated in overfolded Oligocene.

The oil, however, is not concentrated in the saliferous but in the porous beds of the older (Oligocene, Fig. 7) or newer (Pliocene, Fig. 8)

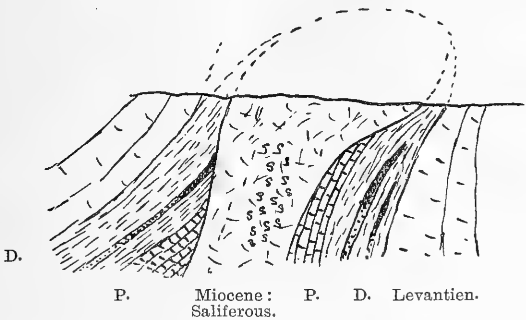


FIG. 8. Oil derived from upfolded saliferous Miocene, but accumulated in contiguous Dacien (D.). Oilfield at Bacoi (diagrammatic section). *sss* indicates masses of rock-salt. P. = Pontien; D. = Dacien.

formations thrust over it or faulted against it. The conditions are very favourable, viz., compression of the oil-generating rocks, relief of pressure above, contact with overlying porous beds, the porous beds inclined and generally sealed at their upper ends.

[1] Professor Mrazec, "Excursions dans les regions pétrolifères de la vallée de la Prehova," p. 62. Congrès International de Pétrole, 1907.

(To be concluded in our next Number.)

VI.—The Rhætic Rocks of Warwickshire.[1]

By L. Richardson, F.R.S.E., F.G.S.

Contents.

I. Introduction.

The distribution of the Rhætic rocks in Warwickshire is not represented on the existing Geological Survey maps because at the time that the survey was made their distinctness from the Lower Lias was not appreciated, and therefore they were represented by the same colour.

In Warwickshire, as in other counties, the Rhætic beds crop out at or near the top of an escarpment, which, as a rule, is very well marked and oft-times really steep. But in the extreme north-eastern portion of the county the usual escarpment is buried beneath a thick accumulation of drift; while from one or two places in the neighbourhood of Stratford-on-Avon it is absent, because the boundary-lines are faults.

The geologist who has contributed most to our knowledge of these beds in Warwickshire is undoubtedly Brodie. From the bottom-beds of the Lias in the county he collected many insect-remains[2]; he described the sections of Rhætic beds on the railway at Summer Hill, near Bidford,[3] and between Ettington and Kineton[4]; he found indications of the Bone-Bed equivalent (in the form of a thin yellow sandstone band crowded with casts of '*Pullastra*') at Knowle, near Birmingham[5]; and obtained most interesting pieces of richly-fossiliferous *Pecten*-Limestone and *Estheria*-Bed from the outliers near Wootton Wawen.[6]

Brodie is followed by Mr. H. B. Woodward, who has noticed the sections at Harbury[7] and Church Lawford,[8] and by the late R. F. Tomes, who collected many fossils from the White Lias of the county.[9] Others who have contributed to our knowledge of the beds in various ways are H. H. Howell,[10] T. Wright,[11] J. W. Kershaw,[12] J. M. Wilson, E. Cleminshaw, and Mr. F. T. Maidwell.[13]

[1] I have to acknowledge my indebtedness to the Government Grant Committee of the Royal Society for assistance towards carrying out the investigations that have resulted in this paper.

[2] *A History of the Fossil Insects in the Secondary Rocks of England*, 1845, pp. 73–9; Trans. Woolhope Nat. F.C., vol. for 1866 (1867), pp. 205–15, etc.

[3] Quart. Journ. Geol. Soc., vol. xlii, pp. 272–5, 1886.

[4] Ibid., vol. xxx, pp. 746–8, 1874.

[5] Ibid., vol. xxi, pp. 159–61, 1865. [6] Ibid., pp. 160–1.

[7] *The Jurassic Rocks of Britain—The Lias of England and Wales* (*Yorkshire excepted*), vol. iii, pp. 151, 159, 160, 1893: Mem. Geol. Surv.

[8] Ibid., pp. 151, 162, 163: Explanation, Hor. Sect., Sheet 140, p. 9.

[9] Q.J.G.S., vol. xxxiv, pp. 179 et seqq., 1878; vol. xl, pp. 353–75, 1884.

[10] *Geology of Warwickshire Coal-field*, 1859, p. 45.

[11] Q.J.G.S., vol. xvi, pp. 394, 395, 1860; Pal. Soc., Monogr. Lias Amm. Brit. Isles, pt. i, pp. 19–21, 1878.

[12] An active local geologist who furnished several authors with valuable information.

[13] Proc. Warwick. Nat. and Arch. F.C., 51st Ann. Rep., 1906, pp. 20–7.

Several observations that have been made by previous workers suggested that an examination of the Warwickshire Rhætic would be attended by more than ordinary interest. The three main observations are in effect—

(*a*) The record of a peculiar bed, called the 'Guinea-Bed', at the very base of the Lower Lias, which, from its lithic and faunal characters, suggests a non-sequence between Lias and Rhætic.

(*b*) That the White Lias proper is present in the county and in places arenaceous.

(*c*) That, in addition to the White Lias being arenaceous, the Black Shales are in places wanting, and that these facts lead to the conclusion that we are not far from the local margin of the deposit.[1]

It may be as well to state at once that the component divisions of the Rhætic Series in Warwickshire are not subject to the considerable changes that the foregoing remarks on their supposed arenaceous and attenuated condition would lead one to suppose. In brief, the Tea-green Marls of the Keuper are the same as usual; the Black Shales are probably continuous through the county (although more deficient in hard bands than usual); the greenish-grey marls of the Upper Rhætic are well-developed, in places containing an *Estheria*-Limestone rich in the characteristic phyllopod; while above, from the neighbourhood of Wimpstone Field north-eastwards to the county-boundary, is White Lias—unmistakable, both as regards its lithic characters and fossil contents. Indeed, this presence of true White Lias (Langport Beds) is the most interesting feature of Warwickshire Rhætic stratigraphy.

In the neighbourhood of Binton, Grafton, Wilmcote, and Bickmarsh, from which, however, the White Lias is absent, occurs the 'Guinea-Bed'. This is a peculiar and frequently conglomeratic stratum, its lithic and faunal characters indicating a non-sequence between it and the immediately subjacent deposit. Some authors have grouped the bed with the Rhætic, others with the Lias, but fuller reference will be made to this matter later.

Above the Guinea-Bed come the alternating deposits of limestone and clay in connexion with which the terms 'firestones', *Ostrea*- and Saurian Beds, and Insect Beds are familiar.

Tea-green Marls.—The line of demarcation between the Tea-green Marls and the Black Shales at the few places where I have seen their junction, and from all accounts, is sharply-defined, and no representatives of the Sully Beds have been or, I think, are likely to be found.

The Tea-green Marls themselves, as already remarked, are of the usual type. Since at one end of the county, namely, at Marl Cliff, they are about 24 feet thick, and at Wigston in Leicestershire, beyond the northern end, about 15 feet thick, it is to be presumed that in the intervening district their thickness lies between these two figures.

There are no good exposures of the Tea-green Marls now available; but I have noted exposures of minor importance at the following localities:—

[1] *The Jurassic Rocks of Britain—The Lias*, etc., p. 151.

(1) Marl Cliff.
(2) Half a mile north of Billesley.
(3) A mile and a half 3° S. of W. of Bearley Junction.
(4) Near Whitehall Farm.
(5) At Atherstone Hill, near Preston-on-Stour.
(6) At Loxley.
(7) At Red Hill, to the north of Ettington Station.
(8) At Chesterton Green, near Harbury.

II. Subdivisions of the Rhætic Rocks recognizable in Warwickshire.

Black Shales or Westbury Beds.—There is now no good exposure of these Black Shales in the county; but a number of sections have been available from time to time when the railways were in course of construction.

From what has been recorded and from specimens that have been obtained, especially from Summer Hill, it is obvious that at certain horizons they are extremely rich in fossils, particularly in specimens of *Pteria contorta* and in species belonging to the genus *Isocyprina*. Hard beds do not seem to be prominently developed; but a number of thin sandstone-layers are reported to occur in the lower portion of the Black Shales in the Summer-Hill railway-cutting; while Brodie obtained numerous masses of highly-fossiliferous *Pecten*-Limestone from temporary excavations at Brown's Wood, which is situated 3½ miles to the west of Bearley Junction. The Bone-Bed, as a stratum rich in vertebrate-remains, appears to be very poorly developed. The only record of it, apparently in its typical condition, is one by Strickland, who observed it, *in situ* it is said, somewhere in the neighbourhood of Bidford.[1] In what is probably its usual condition in Warwickshire, namely, a yellow micaceous sandstone, it has been observed at Knowle and in the railway-cutting near Kineton.

It has not been possible, owing to lack of sections, to determine the precise thickness of the Black Shales. At Dunhampstead, in Worcestershire, they are about 18 ft. 6 in. thick, and at Wigston, near Leicester, 29 ft. 9 in. In Warwickshire it is to be presumed that their thickness lies between these figures, and in my opinion there is no reason for believing that they are absent from anywhere—not even from the Church Lawford neighbourhood.

The sharp line of demarcation between the Black Shales and Tea-green Marls is *ipso facto* suggestive of a non-sequence, and at Snitterfield, near Stratford, Brodie, as long ago as 1886, thought he had evidence that indicated that the Tea-green Marls had been subjected to erosion previous to the deposition of the Black Shales. Be this as it may, the lower limit of the Black Shales in Warwickshire is everywhere, as far as we know, 'sharply-defined.'

This, however, is not the case with regard to the upper limit of the Black Shales, for they merge into the greenish-grey marls of the Upper Rhætic.

Cotham Beds.—These deposits are almost wholly marl of the usual greenish-grey tint, and are continuous throughout the county. No stratum exhibiting Cotham-Marble facies has been detected; but the

[1] Q.J.G.S., vol. xxi, p. 160, 1865.

Estheria-Bed is present; has been proved in a sinking through the floor of a quarry at Wilmcote, near Stratford-on-Avon; and nodule-shaped masses of the usual type, rich in specimens of *Estheriæ*, have been obtained from Brown's Wood, near Wootton Wawen.

Langport Beds.—It is extremely interesting to find the White Lias proper present in Warwickshire, for after leaving the southern portion of Gloucestershire it is not seen again in its typical form until the neighbourhood of Wimpstone Field, near Stratford-on-Avon, is reached. Thence, right through to Rugby, it is well and persistently developed (maximum about 10 feet), of very much the same appearance as the Somerset White Lias, contains specimens of *Dimyodon intus-striatus* (Emmr.) abundantly in places, and not infrequently corals. Certain of its beds are well-bored by annelids, and at Church Lawford portions are pebbly; while in the same neighbourhood it has a ferruginous deposit on top, with which are associated ample indications of erosion by water: in other words, there is abundant evidence for a non-sequence between the White Lias and the superincumbent Lower-Lias deposits.

The White Lias is absent from the neighbourhood of Binton, Grafton, Wilmcote, and Bickmarsh, being "represented", according to Mr. H. B. Woodward, "by the Guinea-Bed."[1]

No sections in which the Guinea-Bed is seen *in situ* are now available; but from a study of the recorded observations of previous workers I am certainly inclined to regard it as the bottom-layer, in the district mentioned, of the Lower Lias.

Lower Lias.—Above the Guinea-Bed come the numerous beds of limestone and clay from which abundant specimens of *Ostrea liassica*, insects, fish, and Crustacean remains have been recorded, and which are known as the 'Firestones' or '*Ostrea*-Beds'[2] and the 'Insect' or 'Saurian Beds'.[3] *Ammonites planorbis* and *A. johnstoni* appear to range throughout. This is puzzling; but apparently, whilst the beds that are richest in insect and Crustacean remains in Somerset come *below* the limestones that contain *Ostrea liassica* in greatest abundance, in Warwickshire they come *above* and are of *planorbis* date.

The interesting point in connexion with the deposits in the neighbourhood of the junction of the Rhætic and Lias beds in Warwickshire is that while the Firestones or *Ostrea*-Beds, Saurian or Insect Beds are present in the district in which the Guinea-Beds occur (and from which the White Lias is absent), they are absent

[1] *The Geology of England and Wales*, 1887, p. 247.

[2] Brodie states (Trans. Woolhope Nat. F.C., vol. for 1866, p. 212) that it is worthy of note that in one of the more westerly sections at Wilmcote "all the insect beds thin out and scarcely amount to three layers, the top band being irregular and shattered; a thick mass of shale succeeds, undivided, as elsewhere, by limestones, and below are three beds of limestone, viz.; the firestone, with *Ostrea liassica*, but of a very different character". From Brodie's record of the Wilmcote section (*loc. cit. supra*, pp. 210–11) it is clear that the limestones in which he found insect-remains most abundantly came *above* the deposits in which saurian-remains are commonest, and are clearly of *planorbis* date.

[3] Brodie complains that his name of "Insect Beds" was ignored by Wright, who applied the term "Saurian Beds" to them (Trans. Woolhope Nat. F.C., vol. for 1866 (1867), p. 210).

from the greater portion of Warwickshire where the true White Lias occurs. There stiff, blackish clays rest directly upon the White Lias.

III. Local Details.

At Marl Cliff the Tea-green Marls are visible, then about 2 feet of black shale, to which follows a layer of sandstone, 1 inch thick, that represents the Bone-Bed.[1]

Summer Hill.—Here the East and West Junction Railway passes through the escarpment of the Rhætic beds in a cutting. When this railway was constructed an excellent section was displayed; but while Brodie has furnished some information, it is unfortunate that his remarks were not more detailed.[2]

According to Brodie, the beds dip to the south-east. At the eastern end of the cutting was an "insect-limestone, probably the bottom one of the series", below which came, in descending order, the Firestone, the *Estheria*-Bed (doubtless embedded in the usual greenish-grey Upper-Rhætic marls), and then the Black Shales. The Black Shales were, in the words of Brodie, "loaded with the usual characteristic fossils" at certain horizons;[3] but whilst he noticed a "band of blue nodular stone in the shales", which probably represented the *Pecten*-Bed, he did not observe any equivalent to the Bone-Bed. Probably it was present as a thin sandstone-layer, like its representative at Marl Cliff and Knowle, near Birmingham.

The escarpment between Summer Hill and the neighbourhood of Newnham is well-marked and in places very steep, but there are no exposures of the Rhætic beds in it.

North-west of Newnham, but on the opposite side of the Alne River, are two outliers of Rhætic beds, namely, those called by Brodie 'Stooper's Wood' and 'Brown's Wood'.

Stooper's Wood Outlier.—This outlier is composed of Rhætic and Lower-Lias beds. The quarry referred to by Brodie at Shellfield is overgrown now, and those from which he obtained evidence of the *Pecten*- and *Estheria*-Beds, the latter containing fragments of *Lycopodites*, were characterized as 'old' by Brodie as long ago as 1865.[4]

Brown's Wood Outlier.—Brodie noticed beds similar to those he saw at Stooper's Wood at Brown's Wood.[5] The 'Insect-Limestones' appear to have been singularly fossiliferous, containing

"a great variety of beautifully-preserved insect-remains . . . a few fragmentary plants (including fronds of fern), and a small shrimp-like Crustacean . . ."

Similarly, the *Pecten*-Bed proved to be highly-fossiliferous, and some of the well-preserved specimens referred to by Brodie[6] are now to be seen in the Warwick Museum. There is also, from the same locality, a piece of limestone crowded with specimens of *Estheria minuta* var. *brodieana*.

[1] L. R., Proc. Cotteswold Nat. F.C., vol. xv, pt. i, p. 41, 1904; Trans. Worcestershire Nat. Club, vol. iii, p. 101.

[2] Q.J.G.S., vol. xlii, pp. 272–3, 1886.

[3] Amongst them *Ophiolepis damesi*. Examples of *Isocyprina* spp., *Pteria contorta*, *Natica oppeli*, etc., in black shale from here are exhibited in the Warwick Museum.

[4] Q.J.G.S., vol. xxi, p. 160, 1865.

[5] Ibid., p. 160.

[6] Ibid., vol. xxx, pp. 748–9, 1874.

Copt-Heath Outlier, near Knowle.—This outlier is composed of Rhætic and basal Lower-Lias deposits. It was discovered by Dr. Lloyd, of Leamington, but was first referred to in print by Strickland[1] and noticed in greater detail by Brodie.[2]

The Lias beds on the occasion of Brodie's first visit were reached by means of a shaft, but from the rock that was excavated Brodie was enabled to determine the presence of the zone of *Ammonites planorbis* and of the Saurian and *Ostrea*-Beds with the usual fossils, but not the Insect Limestone. Traces of the *Pteria-contorta*-Shales were detected and also fragments of a yellow micaceous sandstone with '*Pullastra arenicola*', the equivalent of the Bone-Bed. Subsequently, in 1874, Brodie recorded that he had actually discovered the Insect Limestone, with insect-remains, but was unable to ascertain if there were several beds or only one.[3]

At the present time the spoil of Lower-Lias rocks at the old quarry and a great heap of black shale alongside the canal (which was dug out of it) are all that can be seen, but it is to be hoped that if any building-operations are carried out a sharp watch will be kept for possible exposures.

Wilmcote.—About fifty years ago (about 1860) Kershaw, of Messrs. Greaves & Kershaw, had a sinking made through the floor of one of the quarries at Wilmcote. The 'Firestones' were the lowest beds ordinarily exposed in the quarry, but by the sinking the following beds were proved:—[4]

			ft.	in.
Lower Lias		28. Shale, hard, dark, slaty	1	0
		29. Guinea-Bed. Limestone, hard, shelly	0	1
Rhætic.	Cotham Beds	30. Shale, green, clunchy	3	0
		31. *Estheria*-Bed. Marl, fine-grained, greenish; *E. minuta*, var. *brodieana*	0	3
	Westbury Beds	32–42. Shales, black, with septaria at 19 ft. 9 in. down	26	2
? T.-g. M.		"43. Clay, light, soft brown."		

Wright, who was the first to publish details of this section,[4] gave bed 30 to the "*O. liassica* and Saurian Beds", calling those from 31 to 43 inclusive the "Westbury Beds".

In his *Geology of Oxford* (1871) Phillips reproduces Wright's record from beds 28 to 43 (incl.). But while on p. 105 he groups bed 30 (some "green clunchy clay") with the Rhætic, on p. 110 he places it above the 'Westbury Shales', apparently regarding it as Liassic. There is little doubt that it belongs to the Cotham Beds, that is, to the Upper Rhætic.

Binton.—In a quarry at Binton, now overgrown, Tomes obtained a very interesting assortment of fossils from the Guinea-Bed. It included the tooth of the essentially Rhætic fish *Sargodon tomicus*, along with characteristic Lower-Lias fossils.

[1] *Memoirs of H. E. Strickland*, by Sir William Jardine, 1858, p. 117.

[2] Q.J.G.S., vol. xxi, pp. 159–60, 1865; Rep. Brit. Assoc., 1864, p. 52.

[3] Ibid., p. 748; see also *The Jurassic Rocks of Britain—The Lias*, etc., p. 153.

[4] Wright, Q.J.G.S., vol. xvi, pp. 385–7, 1860.

Some distance away to the west, somewhere in the escarpment, Tomes discovered a number of Rhætic beds. Wright published Tomes's notes in 1860 [1] and reproduced them in his monograph in 1878.[2] In the same year, however, Tomes had occasion to publish the details with which he had furnished Wright; but he made some additions which are very helpful.[3]

Snitterfield.—Brodie, as already mentioned, thought there was evidence in a section displayed in an excavation made in connexion with the waterworks at Snitterfield that the Black Shales rested upon an eroded surface of the Tea-green Marls; [4] but while this may have been the case, doubt has been expressed,[5] and the observation had better not be made use of.

To the south of Stratford-on-Avon the White Lias first appears as rubble on the fields half a mile or so to the south-east of Sweet Knowle; then in a pond-side and in shallow abandoned workings on Wimpstone Field; and next, below the Lower-Lias limestones at Newbold Limeworks. The rock is of a pinkish-grey colour, often 'flinty', has corrugated and waterworn surfaces, and is often pierced by annelid-borings. Ferruginous matter, now oxidized brown, often occurs in the borings and fissures in the stone. Fossils are not numerous in this neighbourhood. An indeterminable species of *Isocyprina* is the most abundant form, and radioles of *Pseudodiadema* and valves of Ostracoda occur sparingly.

White Lias has also been worked at Armscote, on Meer Hill, and extensively at Red Hill and Oakham (to the north of Ettington Station), and is now quarried close to the station.

On the western side of the Dene Valley, that is, between Red Hill and Ettington Station, the White Lias occurs over a considerable area originating noticeably flat ground. The White Lias thence spreads round across the brook and railway, and pursues a north-easterly course to Lighthorne, having been in the past extensively quarried near the barn north of Stamford Hall, at Foss Farm, on Friz Hill, Moreton Hill, near Newbold Barn and Lighthorne itself, and is at present worked on the north side of Compton Verney Park and at Shadwell Barn, the latter the best section in the district.

In all these sections the White Lias is very similar in appearance, much resembling the Somerset White Lias. In places it is rich in specimens of *Dimyodon intusstriatus* and *Pseudomonotis fallax*, while ostracods and broken radioles of *Pseudodiadema* are not uncommon. The beds are between 6 and 10 feet thick, and most of the component layers are bored by annelids and oft-times have well-waterworn surfaces encrusted with the characteristic *Dimyodon*, facts denoting slow formation.

In a quarry near Compton Park tough black clay, familiar in sections further north, occurs immediately above the White Lias.

[1] Q.J.G.S., vol. xvi, pp. 394–5, 1860.

[2] Pal. Soc., Monogr. Lias Amm. Brit. Isles, pt. i, pp. 19–21, 1878; see also Phillips, *Geology of Oxford*, pp. 111–12.

[3] Q.J.G.S., vol. xxxiv, pp. 181–2, 1878. Strickland discovered the Bone-Bed *in situ* at Temple Grafton (Brodie, *Fossil Insects*, p. 73).

[4] Ibid., vol. xlii, pp. 273–4, 1886.

[5] Discussion, ibid., pp. 274–5.

It is interesting to find this clay thus far south in immediate contact with the White Lias, for I think there is no doubt that the deposits are non-sequentially related, that the Insect and associated beds, to say the least, are absent from in between.

Abundant evidence of the White Lias is to be obtained in certain of the railway-cuttings between Ettington and Kineton, along with the underlying Upper-Rhætic greenish-grey marls, in which, in the cutting nearest the River Dene, Brodie discovered the *Estheria*-Bed. In the same cutting he noticed the *Pteria-contorta*-Shales below, and in that near Butler's Marston the *Estheria*-Bed and greenish-grey marls and

"about twenty feet of black shale . . . at the west end of the cutting overlain by drift. Further on, beyond the ridge nearest to Kineton, these black shales (*Avicula contorta* zone) may be traced, having included fragmentary pieces of yellow micaceous sandstone, the *Pullastra arenicola* bed . . . The White Lias is again exposed in the section beyond, broken up on the top, underlain by the '*Estheria*-bed'".

The White Lias has been extensively worked in the past at Sitch Field, on the outlying Barn Hill, while there are two quarries at present in work near Chesterton Church. In the neighbourhood of Chesterton Windmill are numerous small openings in the White Lias, but the best is that situated a quarter of a mile to the north of the windmill.

The quarry referred to is on a line of fault and the beds are much disturbed. At the top are the tough blue Lias clays, then the rusty layer, followed by 6 to 8 feet of White Lias, and lowermost some greenish-grey marls (Cotham Beds). The surfaces of most of the limestone-beds are waterworn, some are bored by annelids, and many have specimens of *Dimyodon* adhering.

Harbury.—At Harbury the Rhætic escarpment is traversed by a deep railway-cutting. The only rock well exposed is the White Lias.

The Red Keuper Marls are seen in the brook-sides near the level-crossing at the western end of the cutting; the Tea-green Marls succeed and are followed by the *Pteria-contorta*-Shales, which, however, are only seen in the form of material worked out by the rabbits. The greenish-grey marls of the Cotham Beds are similarly exposed, and, for them, are of considerable thickness. The White Lias is very conspicuous and forms an inclined bench on both sides of the cutting. The upper beds, as usual in Warwickshire, are more massive than the lower. The top-layer has a waterworn surface, is iron-stained and crowded with fossils, particularly with specimens of *Isocyprina*.

Other fossils from the White Lias here are *Dimyodon intusstriatus*, *Plagiostoma valoniense*, *Pleuromya crowcombeia* auctt., *Pseudomonotis*, *Plicatula* cf. *cloacina*, Vaughan, *Volsella minima*, Moore *non* Sow., *Montlivaltia tomesi*, *Pseudopedina tomesi*, and Ostracoda.

The tough blue clays of the type common to the base of the Lower Lias in this part of Warwickshire succeed and are followed by the *Angulatus*-Beds, which are rich in pyritized specimens of *Schlotheimia*. No indications of the *Ostrea*- and Insect Beds have been observed, and the *Planorbis*-Beds, if present, are represented by clay or shales.

Mr. H. B. Woodward has briefly noticed this section; but the

White-Lias beds are not so arenaceous as his statement that they are 'somewhat sandy' would lead one to suppose.[1]

Between Harbury and Ufton there are two quarries in the White Lias, and formerly there were extensive workings at Stoneythorpe.[2]

Many fossils from the White Lias have been obtained from Bascote, Print Hill, and the neighbourhoods of Long Itchington and Stockton. Some are now housed in the Museum at Warwick.

There are no sections of the Rhætic beds between Long Itchington and Church Lawford.

At Church Lawford, however, the buried escarpment of the Rhætic is cut through by the Rugby and Coventry Branch of the London and North-Western Railway. At the time that the railway was constructed there must have been displayed a most interesting section, showing the sequence of deposits from the Red Marls of the Keuper to the *Angulatus*-Beds of the Lower Lias. But now nothing more than the White Lias, the very bottom-portion of shaly clays and Drift, can be seen: all the other beds are hidden by grass.

The White Lias is much fissured, the cracks are filled in with calcite, and in places it is very ferruginous. The beds on the whole are singularly barren of fossils, and the top-band is "pebbly" and has a waterworn, bored, and pitted upper surface. A similar bored bed has apparently been observed in

"the bed of the Church Lawford Brook, on the left-hand side of the road. The surface of the rock pierced by these worms is very peculiar and striking, every square inch being indented with their burrows".[3]

Resting directly upon the White Lias are clayey shales. The greater portion of these shales is replete with the radioles and portions of the tests of *Cidaris*. Owing to the long exposure of the clay-banks remains of specimens of *Cidaris* appear to occur in the bottom-portion of the clays on top of the White Lias; but Mr. E. Cleminshaw tells me that he has collected examples of *Ammonites planorbis* here, and he thinks that about the lowest 3 feet of the shale-deposit belongs to the *Planorbis*-Zone. The *Cidaris*-Shales appear to be comparable with those that were exposed in the cuttings on the new South Wales Direct Line near Chipping Sodbury.[4] There they were separated from what remains of the White Lias by the *Ostrea*- and *Torus*- (or *Johnstoni*)-Beds: the true *Planorbis*-Zone was not represented. Here, on the other hand, the *Ostrea*-Beds do not appear to be represented: the *Planorbis*-Shales apparently rest non-sequentially upon the White Lias.

The *Cidaris*-Shales are succeeded by the *Angulatus*-Beds, whose limestones—usually with those of the overlying *Bucklandi*-Beds—are so extensively worked for burning for lime at the large Portland Cement Works at Newbold-on-Avon,[5] New Bilton (near

[1] *The Jurassic Rocks of Britain—The Lias*, etc., vol. iii, p. 159, 1893.

[2] Q.J.G.S., vol. xl, p. 364, 1884.

[3] T. B. Oldham, Report Rugby Sch. Nat. Hist. Soc., 1879, p. 11.

[4] Q.J.G.S., vol. lviii, pp. 720–1, 1902.

[5] In some of the indurated shales Ostracoda are very abundant, together with specimens of *Pseudomonotis papyria* (Qu.), and indicate precisely the same horizon as at Maisemore, near Gloucester (Proc. Cotteswold Nat. F.C., vol. xv, pp. 256–62).

Rugby), Long Itchington, Harbury, and Upper Goldicot, near Ettington (near Stratford).

Mr. H. B. Woodward is the only author who has recorded any details of the Church-Lawford section.[1] He observed the *Cidaris*-Shales resting upon "greenish-grey marl, 5 to 8 feet" thick, and these in turn upon the red and green marls of the Keuper. He stated that it is noteworthy that the *Pteria-contorta*-Shales "are not represented at this locality", and elsewhere adds[2] "nor in the Rugby well, and they are poorly represented in other parts of Warwickshire".

J. M. Wilson recorded the details of the well-sinking[3] referred to by Mr. Woodward. Mr. Woodward's conclusion that the Black Shales are absent from beneath Rugby depends upon the identification of 10 feet of 'hard light stone', which rests upon 'red clay', that is, Keuper Marls. Mr. Woodward regards this 'hard light stone' as White Lias.[4] I am inclined to follow J. M. Wilson, who considered the 12-foot bed of limestone reached at a depth of from 390 to 402 feet from the surface that subdivision, and Wilson's "dark and brown clays [58 feet]" and "black clay [20 feet]" the equivalents of the Cotham and Westbury Beds of the Rhætic. The 'hard light stone', according to this view, would be Tea-green Marl (Keuper).

In times past the White Lias was frequently exposed in the neighbourhood of Church Lawford, and a number of fossils have been recorded.[5] But now all the small lime-works have been closed, and the only place at which I noticed traces of White Lias was at the locality called 'Bath', near Kings Newnham. Here there are a great number of old kilns, mainly constructed of White Lias that was doubtless obtained from the workings. The pieces of rock built into the kiln walls are, except for what must have been the top-bed, scantily-fossiliferous. This top-bed is very ferruginous, extremely rich in specimens of *Pseudomonotis*, and has a waterworn and bored upper surface. Thence northwards to the county-boundary the solid rocks are hidden by drift.

NOTICES OF MEMOIRS.

I.—A Remarkable Sarsen or Greywether.[6] By A. Irving, D.Sc., B.A.[7]

WITHOUT desiring to add to the existing plethora of literature on these rocks the author thinks that this sarsen is worth special notice. It was discovered last winter in digging a grave in the

[1] *The Jurassic Rocks of Britain—The Lias*, etc., pp. 151, 162.

[2] Horizontal Section (Geol. Surv.), Sheet 140, and Explanation, 1891, p. 10.

[3] Report Rugby Sch. Nat. Hist. Soc., 1868, pp. 41–2 and plate.

[4] *The Jurassic Rocks of Britain—The Lias*, etc., p. 165.

[5] E. Cleminshaw, Report Rugby Sch. Nat. Hist. Soc., 1867, p. 32; ibid., 1868, p. 43; T. B. Oldham & G. Jones, ibid., 1877, p. 48; T. B. Oldham, ibid., pp. 49–54.

[6] A popular account of this block was given by the author in the *Herts and Essex Observer*, January 7, 1911.

[7] Read before Section C (Geology), British Association, Portsmouth, September, 1911.

Bishop's Stortford Town Cemetery, about 7 feet from the surface in the principal Boulder-clay of the district, the equivalent of the Chalky Boulder-clay of the Eastern Counties.

The block is fairly angular, approximately a cube. On one side the fracture of the bed is fairly fresh; the opposite side is slightly hollowed, as if by the long-continued current action of a shingly stream. For the greater part of its thickness it is a true sarsen; towards the base a few flint pebbles are scattered through it; the upper surface passes into a true 'puddingstone' (an agglutinated mass of flint pebbles), the matrix of which is lithologically the same as, and continuous with, the material of the sarsen. About the middle of the upper side the agglutinated mass of pebbles fills a small gully in the quondam sand of the sarsen. A subordinate alternation of the true sarsen structure with the pebble-bed structure is seen in the largest examples of puddingstone perhaps in the county.[1] A striking lithological feature of this specimen is the distribution in it of numerous small, angular bleached fragments of flint. Its dimensions are 30 × 20 × 18 inches, and its weight not less than half a ton. No trace of glacial striations has been detected on it.

The author refers to his former work on the genesis and distribution of sarsens.[2] While recognizing their common occurrence in the Lower Eocenes, and even in the sands of the Neocomian, he regards those of the interior of the London Basin as the wreckage of a younger formation (late Eocene or Oligocene), possibly the stratigraphical freshwater equivalents of the *Stettiner Sandstein* of North Germany[3] and the *Grès de Fontainebleau*[4] of the Paris Basin. Agglutinated portions of the Bagshot Pebble Beds in situ, with similar siliceous cementation, are known to occur;[5] there is good evidence of the quondam extension of the younger beds of the Bagshot Series (including the pebble beds) over Herts and Essex; and the author points to this recently unearthed rock-mass as tending to clinch the view advocated by him for years past—that the sarsens and the Herts 'puddingstone' are remnants of one and the same *younger* Eocene (or Oligocene) formation.[6] He considers the latest treatment of the subject by the late Professor T. Rupert Jones, F.R.S., and the more recent treatment of it by H. B. Woodward, F.R.S.,[7] inadequate.

[1] Seen in the grounds of G. E. Pritchett, Esq., F.S.A., Oak Hall, Bishop's Stortford.

[2] P.G.A., viii, No. 3, 1883, where critical reference is made to the views of the late Professor John Phillips, F.R.S., of Oxford.

[3] H. Credner, *Géologie* (Leipzig), 10th ed., pp. 692 ff.

[4] S. Meunier, *Les causes actuelles en Géologie*, p. 289; Credner, op. cit., p. 683.

[5] A. Irving, P.G.A., xv, pp. 196, 236, February, 1898.

[6] A. Irving, "High Level Plateau Gravels, etc.": Geol. Mag., No. 484, October, 1904.

[7] *The Geology of the London District* (Mem. Geol. Surv., 1909).

REVIEWS.

I.—Scottish Geological Survey Memoirs.

1. The Geology of the Glasgow District. By C. T. Clough, L. W. Hinxman, the late J. S. Grant Wilson, C. B. Crampton, W. B. Wright, E. B. Bailey, E. M. Anderson, and R. G. Carruthers. With contributions from G. W. Grabham, J. S. Flett, and G. W. Lee. 8vo; pp. x, 270, with 33 text-illustrations and 1 contour map. 1911. Price 4*s.* 6*d.*

If many hands make light work the production of this memoir ought to have been an easy task, especially as the above list does not contain the names of all who were officially engaged in the Geological Survey of the area, the original maps (published 1870–8) having been the work of E. Hull, J. Geikie, B. N. Peach, and R. L. Jack. Moreover, there are contributions in the memoir from other members of the Survey: notes on fire-clays by J. Allen Howe, with analyses by E. G. Radley, and a bibliography by D. Tait. The colour-printed map which accompanies the present memoir includes portions of the Sheets 22, 23, 30, and 31, the geology has been thoroughly revised, and the map (price 2*s.*) has been specially prepared for economic and educational purposes, with Glasgow as a centre. The map itself contains a wonderful amount of information, the details of the basaltic rocks being enough to appal an ordinary student; it is, however, very clearly printed, and the Glacial Drift is shown by different patterns of stippling.

The Old Red Sandstone, the oldest formation in the district, is separated into Upper and Lower divisions, which are unconformable and palæontologically distinct. Nevertheless, the evidence of these features has to be sought in other areas, as no fossils have been found locally, and "there is no direct evidence of the unconformity elsewhere so strikingly developed". The view is favoured that the Old Red Sandstone was formed under continental conditions with desert, lacustrine, and river action; while the cornstones of the Upper division are likened by Mr. H. B. Maufe to the 'kankar', which in India and Central Africa has been formed in areas subject to wet and dry seasons.

To the Carboniferous rocks Glasgow owes much of its wealth and importance, and full particulars are given of the Calciferous Sandstone Series, with its many basaltic lava-flows, of the Carboniferous Limestone Series, the Millstone Grit, the Productive Coal-measures, and the Upper Barren Red Measures. Practical information is given concerning the coals, the correlation of seams, the cement-stones, limestones, ironstones, and fire-clays. The conditions of sedimentation are dealt with both in the stratigraphical and palæontological chapters, and in the latter due acknowledgment is made of the classic work of the Rev. David Ure, *The History of Rutherglen and East Kilbride*, published in 1793. In that work many of the familiar fossils, the names of which appear in the lists from the Carboniferous rocks of Britain and the Continent, were described for the first time. There is much of interest in the chapter contributed by Dr. Lee, whose initials

(G. W. L.) appended to his work happen to coincide with those of another member of the Survey, Mr. Lamplugh. In regard to the marine beds Dr. Lee points out that "Similarity of conditions induced a similarity in the nature of the fauna". Thus certain abundantly represented species disappear more or less suddenly, and then reappear at a higher horizon, or in other cases vanish altogether so far as this region is concerned. Changes in the position of the shore-line, or of the rivers and marine currents, are justly considered to have influenced the distribution of many organisms.

The Igneous rocks include the Carboniferous lava-flows of the Campsie Fells and Kilpatrick Hills on the north, and those of the Cathkin Hills in the south. Descriptions are also given of various volcanic vents, dykes, sills, etc.

The general structure of the ground is described in a separate chapter, and illustrated by a longitudinal section on the colour-printed map, and by other sections in the text; the faults also are described, some having throws of about 300 fathoms.

No attempt is made to give a complete account of the glaciation of the area, or to describe in detail the Pleistocene deposits of the Clyde Valley. The pre-Glacial topography of Glasgow and its immediate neighbourhood is shown on a colour-printed map, depicting the land as it stood at least 300 feet above present level. A depression of the area almost to present level then took place, accompanied by silting up of valleys. Afterwards came the advance of the great ice-sheet, from the north and north-west, the deposition of boulder-clay, and the formation of drumlins, etc. The retreat of the ice was followed (1) by the accumulation of the 100 foot beach-deposits with sub-Arctic fauna, (2) by elevation and the formation of the 50 foot beach, and (3) after other changes, of the 25 foot beach. The present physical features and river-systems are described, and reference is made to the influence of geography and geology on the rise and progress of Glasgow.

A chapter on Economic Geology, illustrated with figures of micro-slides of rocks, gives abundant practical information relating to the products of the Carboniferous rocks as before mentioned, with particulars of Lime and Cement, Sands, Brick-clays, Paving-setts, Road-metal, and Building-stones. The Building-stones are mostly Carboniferous sandstone, but it is noted that Portland Stone has been introduced. The subject of Water Supply is also dealt with, Glasgow receiving water from Loch Katrine, 34 miles distant. Two wells over 1,000 feet deep are mentioned, one of them yielding highly saline water.

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2. The Geology of Colonsay and Oronsay, with part of the Ross of Mull. By E. H. Cunningham Craig, W. B. Wright, and E. B. Bailey; with notes by C. T. Clough and J. S. Flett. 8vo; pp. viii, 109, with 21 text-illustrations and 6 plates. 1911. Price 2*s.* 6*d.*

It is perhaps unfortunate that the colour-printed map Sheet 35 (price 2*s.* 6*d.*), of which this memoir is descriptive, contains no part of Oronsay and not quite the whole of Colonsay. The missing portions might have been inserted, in the space of about nine square inches, on the broad margin of the map. An uncoloured geological map, on the scale of 2 miles to 1 inch, of the two islands is, however, given in the frontispiece to the memoir. The geology of the islands, described in Part I, is by Messrs. Wright and Bailey. The Lewisian Gneiss is exposed over a few acres in the north of Colonsay, but it is mainly covered by Blown Sand. The two islands of Colonsay and Oronsay are formed chiefly of Torridonian, a single conformable series, probably 5,000 feet thick, composed of grits or arkoses, epidotic beds, sandstones, flags, mudstones, phyllites, and limestones. These are shown on the map in eight divisions, which embrace in all seventeen minor lithological divisions. The mapping clearly shows the general structure of the strata, which dip to the east and north-east, but it is remarked that there is much complexity of minor folding in the series. In a footnote the authors state: "Without in the least suggesting a correlation, it is interesting to note that in all save metamorphism the Colonsay flags resemble the banded semi-siliceous granulites known as 'Moines' in the Central Highlands." Considerable attention has been given to the cleavages in the Torridonian and associated rocks.

The igneous rocks include the syenite of Kiloran Bay, the diorite of Scalasaig, and the kentallenite of Balnahard; also minor intrusions of lamprophyre, basalt, and felsite, and certain north-west dykes of dolerite and monchiquite.

Evidences of severe glaciation are seen in the small area of Lewisian gneiss and elsewhere—glaciation that was effected by ice from the mainland from east to west. Support is given to the view of the glacial origin of the sea-floor basin between Oronsay and Colonsay, as advocated many years ago by Professor J. Geikie. The few sections of Boulder-clay show it in an oxidized form as a red and often stiff and tenacious clay, which forms wet rushy ground. There are also many scattered boulders.

Post-Glacial raised beaches occur at the 100, 50, and 25 foot levels, the last named having been formed during early Neolithic times, in a period of marked cave formation. A brief account is given of the submerged Forest of Loch Fada, Colonsay, where stumps and large trunks of trees (including Goat Willow) occur. It is observed that no trees of the size exist in the valley at the present day, with the exception of the artificially protected plantations and woods at Kiloran. The submergence seems to have been caused by a later transgression of the lake due to the raising of its outlet by the growth of peat.

The islands nowhere attain an elevation of 500 feet, and are probably a remnant of an old plain, 400 to 500 feet above sea-level, to the age of which, however, there is no clue. There is evidence of pre-Glacial marine erosion in a plain, with ancient sea-cliffs, at an elevation of 135 feet. Among other interesting observations are those made on the development of the present topography. There is a good deal of fertile land, largely due to the distribution of shell-sand by winds. The debris from crags of phyllite affords good soil for pasture-land, and the raised beaches a lighter soil suitable for corn. The scenery has many points of great beauty, and the islands may be visited in summer; but sometimes they are "in the winter season for weeks together out of communication with the main land except by telegraph".

Part II, on part of the Ross of Mull and adjacent islands, is by Mr. Craig. The area of Mull, mostly under 400 feet in elevation, is a rough and craggy district of red granite with fine sandy bays. The granite is quarried in the district to the north of that shown on the map. It is regarded as of later Palæozoic age, and it sends veins into the Moine Series. J. G. Goodchild's view that "granite veins have evidently eaten their way into the surrounding rock" is mentioned, but not discussed. The Moine Series consists of metamorphic schists, with intrusive sills of hornblende schist containing abundant garnets. The north-west dykes of dolerite, camptonite, and monchiquite may possibly all be of Tertiary age, like the sheets of columnar dolerite and the two tiny intrusions of granophyre.

Glacial drift mostly occupies small hollows; raised beaches occur as on Colonsay, and there are tracts of shelly blown sand and peat mosses.

II.—Russian Fossil Elephants.

Les Éléphants fossiles de la Russie. By Marie Pavlow. Nouveaux Mémoires de la Société impériale des Naturalistes de Moscou, vol. xvii, pt. ii, pp. 57, 3 plates, 1910.

THIS important memoir by Madame Pavlow describes in detail a quantity of proboscidean remains for the most part from the early Pleistocene deposits of Tiraspol in Southern Russia, but also from other localities. Most of the specimens were originally referred to the species *Elephas trogontherii*, Pohlig, which is, in fact, a primitive form of the Mammoth, but on further examination of the remains the author has come to the conclusion that many of them represent a still more primitive type in which the plates of the molars are wider and fewer in number; to this form she has given the name *Elephas wuesti*.

In discussing the nomenclature of the cheek-teeth in elephants the author objects to the use of the term 'milk-molars' for the three anterior molars, on the ground that they are not replaced by pre-molars. Since, however, from the history of the dentition in the group, it is certain that the replacing pre-molars have only lately been suppressed, some even occurring in one species of *Elephas* proper (*E. planifrons*), it is certain that these anterior molars are homologous with the milk-molars of ordinary mammals, and nothing is gained by concealing this fact by giving them other names.

In addition to *E. wuesti*, remains of several other species of *Elephas*, e.g. *E. antiquus* and *E. armeniacus*, are described from the same deposits: this assemblage does not seem very probable, and perhaps sufficient allowance has not been made for the considerable range of individual variation that may occur in elephant molars.

In the last part of the paper Madame Pavlow discusses the relationship of the later elephants to one another. She is of opinion that the Mammoth and the Indian elephant are not so nearly related to one another as is commonly believed, and that, in fact, they had a different ancestry, the Mammoth being descended from a broad-plated type of *E. meridionalis* through *E. wuesti* and *trogontherii*, while the Indian species are descended from a thin-plated form of *E. meridionalis* through *E. antiquus* and *E. namadicus*. It seems, however, more probable that both the Mammoth and the Indian elephant are descended from some such species as *E. armeniacus*, which is very near to *E. wuesti*. The African elephant is regarded as having sprung from *E. namadicus* through *E. priscus*.

Although it is not always possible to agree with the author's conclusions, her detailed and careful descriptions of these Russian elephants make a very important contribution to our knowledge of the group.

C. W. Andrews.

III.—Über die innere Organisation und Stammesgeschichte einiger irregulärer Seeigel der obern Kreide. (On the Internal Structure and Phylogeny of some Irregular Sea-urchins of the Upper Chalk.) Von Dr. Franz Klinghardt. Jena, 1911.[1]

By a study of the flint-casts and of the cleaned interiors of the tests of certain Cretaceous sea-urchins, Dr. Franz Klinghardt establishes points of extreme interest with regard to the comparative morphology of various fossil and recent echinoids. The material examined was collected from the Senonian of the South of England, the Maestrichtian of Maestricht, and the Danian of Malmö, Sweden; and recent specimens were studied at the biological stations at Plymouth and Lowestoft. Frequent reference is made to the recent *Spatangus purpureus*, since it admits of close comparison with the common *Micraster* of the English Senonian.

Particular attention is paid to the impressions on casts of the intestinal tract, and of the supports of the mouth, the gonads, and the water-vascular system. Dr. Klinghardt points out that in many casts the exact course of the alimentary canal and its mesenteries can be traced, and he is thus able to institute a comparison amongst the following forms: *Ananchytes ovatus*, *Hemipneustes radiatus*, *Micraster cor-anguinum*, and *Echinoconus albogalerus*. The mouth-supporting apparatus has been considered in detail, and the significance of its fuller development in *Spatangus purpureus* than in *Micraster cor-anguinum* has been pointed out. In the discussion of the impressions left by the gonads, the statement of Hoffman that they projected into the body-cavity is shown to be incorrect. In some of Dr. Klinghardt's fossil casts the position and form of the ampullæ, which in recent urchins may be found occupied partly by water and partly by sand and mud, were found to be still clearly indicated, their various degrees of contraction being recognizable. The author's minute examination of the traces of the water-vascular system establishes most interesting resemblances and differences between fossil and recent echini. In one specimen, for instance, the ampullæ

[1] Inaugural-Dissertation zur Erlangung der Doktorwürde der math.-nat. Fakultät der Grossherzogl. Bad. Albert-Ludwigs-Universität zu Freiburg im Breisgau vorgelegt von Franz Klinghardt. Jena, 1911. (Privately printed.)

are indicated by an apparently chalky deposit, their condition being thus analogous to the sand-filled ampullæ of some recent Spatangids.

Among the minor points discussed are the traces of the cœlomic epithelium in *Echinoconus*, the rudimentary perignathic girdle in *Ananchytes*, and the notable differences, chiefly in the disposition of the pores, between the inside and the outside of the ambulacra of *Echinoconus*. Furthermore, the growth-bands in *Spatangus purpureus* and *Micraster cor-anguinum* are shown to be similar. Dr. Klinghardt's examination of specimens of *Ananchytes* from the Danian of Malmö and the Senonian of England has enabled him to determine that changes have taken place in their internal organization at different horizons as well as in the shape-variations familiar to chalk-workers. The positions of the gut-line and of the water-vascular system in particular show these changes. Another interesting fact is brought forward, viz., that one finds in specimens from the *Marsupites*-zone a slight swelling of the ambulacral plates in the direction of the inter-ambulacra. As a result of this, the water-vascular system comes to lie in a kind of channel: the fine peristomial structure has in consequence gradually shrunk, and has disappeared altogether in examples from Malmö. The important conclusion derived from a detailed comparison between *Spatangus purpureus* and *Micraster* is that *Spatangus* recapitulates the *Micraster*-stage in its ontogeny.

In addition to the purely palæontological details, Dr. Klinghardt has furnished many observations of great geological interest. At Newhaven he noted a deposit in process of formation that he considers to explain the origin of echinoderm breccias. This was a silt, rich in broken echinoderm tests, that had accumulated in a sheltered creek, but owing to the incursions of rough seas had come to be intercalated with coarse-textured bands containing a different fauna. The enormous preponderance of small urchins in some marine beds is shown to be due to the fact that the larger species of which fragments are found had swallowed them together with sea-sand. The Newhaven and the Petersberg (Maestrichtian) echinoderm breccias are proved to have been formed under precisely similar conditions.

Dr. Klinghardt attributes the preservation in flint of the form of the internal organs of fossil sea-urchins to rapid infilling of their tests, due to *sudden* precipitation of silica. In support of this opinion he instances the uniformity of the thickness and sharp definition of the tabular flint bands to be found at certain horizons in the English Chalk. The paper concludes with observations on the œcology of living echinoderms; and reasons are assigned for regarding the variations in the facies of *Ananchytes* and *Micraster* as attributable to differences in nature of habitats.

C. P. Chatwin.

IV.—Cambrian Geology and Palæontology. No. 6: *Olenellus* and other Genera of the Mesonacidæ. Smithsonian Miscellaneous Collections, vol. liii, 1910.

SINCE the publication of the memoir on the *Olenellus* fauna in 1891, Dr. C. D. Walcott has made a large collection of these primitive forms from the Lower Cambrian rocks of the United States, Canada, and Newfoundland, and has also further examined those derived from rocks of the same age in Britain and Scandinavia. In some of the American rocks very diminutive specimens, representing the early stages of growth of these Trilobites, have been preserved, and from them the author has endeavoured to trace out their lines of development. These fresh discoveries have also provided materials for a thorough revision of the classification of the group, which is worked out in considerable detail. The author states that with the exception of forms referred to *Nevadia* and *Callavia*, in which a small anterior glabellar lobe is present, the variations in the characters of the cephalon throughout the group are only of specific value; and as the pygidium also is essentially similar, the basis for generic separation mainly depends on modifications of the thorax. Five new genera, *Nevadia*, *Pædumias*, *Peachella*, and *Wanneria*, are introduced, and many new species are described and figured on the twenty-two plates. The use of the family term Mesonacidæ in preference to Olenellidæ is justified on the ground that the former has the priority, and that the genus *Mesonacis* is more typical of the family than *Olenellus*.

V.—A Guide to the Fossil Invertebrate Animals in the Department of Geology and Palæontology in the British Museum (Natural History). Second Edition. 8vo; pp. x, 184, with 7 plates. Printed by order of the Trustees. London, 1911. Price 1*s.*

THE first edition of this admirable guide was published in 1907. In the present one may be noticed the omission of a separate account of the Koenig and Gilbertson Collections (p. 9), owing to the specimens having been dispersed among the systematic series. The addition of the Archæocyathinæ (p. 42). A revised account of the Cirripedia (p. 94). Several alterations due to the rearrangement of the Brachiopoda (p. 114). An Appendix (p. 117) noting recent additions to the exhibited series of Mollusca. Fig. 41 is an original figure of the under-surface of *Eurypterus Fischeri*. Fig. 49 is from a new drawing of *Protocarcinus longipes*. Fig. 65*a* represents a Senonian species of *Membranipora*. In making some of these alterations the author, Dr. F. A. Bather, acknowledges the help of Dr. W. T. Calman, Messrs. R. B. Newton, W. D. Lang, and T. H. Withers. The figures throughout the Guide are admirable.

VI.—Grundzüge der Paläontologie.—The preparation of a new edition, the third, of this well-known textbook of Palæontology of the late Professor K. A. v. Zittel, has been carried out by Professor Dr. F. Broili, of Munich, whose friendly help in correcting the proofs of the two earlier editions was gratefully acknowledged by the author of the work. The first part of the present edition, comprising the Invertebrata, is a volume of 607 pages, with 1,414 text-figures and a separate index. About seventy of the figures are new, and to a large number of the older clichés further explanatory letterings have been added. Dr. Broili has endeavoured to incorporate in the volume all the recent discoveries in Invertebrate Palæontology; references are given to the new literature on the subject which has appeared since 1903, the date of the second edition, and special notice is devoted to the vertical geological range of particular forms.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

I.—*November* 22, 1911.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "Petrological Notes on Guernsey, Herm, Sark, and Alderney." By Professor T. G. Bonney, Sc.D., LL.D., F.R.S., F.G.S., and the Rev. Edwin Hill, M.A., F.G.S.

The authors returned to these islands, after an interval of nineteen years, in order to give further study to the relations of the igneous masses and especially of certain dyke-rocks. As they had themselves suspected in 1891, and as Mr. J. Parkinson had announced in 1907, the old distinction between diorite and syenite could not be maintained; but there existed, especially in Guernsey and Alderney, a dioritic magma which underwent differentiation. The results of this are described, the most basic being found at Fort Albert (Alderney) and Bon Repos Bay (Guernsey), and the most acid, which are really tonalites, more especially in the north-west of the latter island. These and a felspathic variety sometimes intrude, sometimes pass into the others, so they also must have been at high temperature. The so-called 'granites' at the two ends of Sark are hornblendic, the southern one being really a tonalite; so are those of Alderney, Herm, Jethou, and Guernsey, and it is suggested that these granites may be yet more acid terms in a differentiation series.

Of the numerous dykes the most acid are either aplitic micro-granites or quartz-felsites, the latter being the rarer and probably later in date. Some of the former at Castle Cornet exhibit an interesting structure. Here diorite cuts gneiss, and has partly melted down a little of it. Microgranite has also cut and melted some of the diorite, the result being a streaked red and green rock. Diabase dykes are common, and mica-traps have been found in all the islands except Herm. The former almost invariably cut the microgranitic dykes, but are cut by the quartz-felsites.

At Pleinmont, in the south-west of Guernsey, a mass resembling a greenstone proves, as mentioned by the late Père Noury, to be sedimentary. This has been examined and is considered to be, like the 'argillites' of Jersey, Brioverian in age. It is cut by dykes of quartz-felsite and by one of diabase (older than these).

The time-relations of the several rocks are discussed. The gneiss of Guernsey, a pressure-modified granite, is the oldest, and had acquired its structure before the intrusion of the diorites. They were followed by the hornblendic granites, and these by the aplitic microgranites. All were pre-Cambrian, and perhaps even the last was older than the Brioverian. The date of the diabase dykes is more uncertain. They are apparently earlier than the quartz-felsite dykes, which may possibly be of the same age as the acid lavas below the conglomerate of Eastern Jersey, now regarded as basal Cambrian; but in Alderney two diabase dykes cut the *grès feldspathique*. There is, however, reason to think that these dykes are of more than one age. The mica-traps are probably late Palæozoic.

2. "The Evolution of *Inoceramus* in the Cretaceous Period." By Henry Woods, M.A., F.G.S., Lecturer in Palæozoology in the University of Cambridge.

The species of *Inoceramus* found in the Gault, the Upper Greensand, and the Chalk are considered to have descended from two stocks which occur in the Lower Greensand, one being *I. salomoni*, d'Orb., the other of the type of *I. neocomiensis*, d'Orb.

I. *I. concentricus*, Park. (Lower and Upper Gault), is of the same type as *I. salomoni* (Folkestone Beds and *Mammillatum* Bed), from which it has been derived by the reduction in the length of the hinge-line and in the height of the hinge-area, accompanied by a greater obliquity of the axis of growth.

I. sulcatus, Park. (Upper Gault), closely resembles *I. concentricus*, except that it possesses strong radial ribs. Between these two species every gradation is seen in the form known as *I. concentricus*, var. *subsulcatus*, Wiltsh. (Upper Gault), which in its early stage is identical with *I. concentricus*, but at a later stage develops radial folds; the *concentricus* stage may be of long or short duration, and consequently in some cases the folds occur near the margin of the valves only, but in others may reach to near the umbo, while in *I. sulcatus* they reach to the apex of the umbo.

I. tenuis, Mant. (Red Chalk and Chalk Marl), is allied to *I. concentricus*, from which it has been derived by an increase in the length of the hinge and a decrease in the prominence of the left umbo. *I. etheridgei*, Woods (zone of *P. asper* to zone of *H. subglobosus*), is similar to *I. tenuis*, but its left umbo is smaller, the valves less unequal, and the postero-dorsal region is less compressed.

II. *I. anglicus*, Woods (Gault and Upper Greensand), resembles *I. neocomiensis*, but the posterior part of the shell has become more compressed, and the ventral curvature of the ribs has increased. From *I. anglicus* two species appear to have arisen, namely, *I. pictus* and *I. crippsi*.

A. *I. pictus*, Sow. (Chalk Marl to *H. subglobosus* zone), approaches the form of *I. anglicus*, which has more numerous and more regular ribs; and in it the ribs have become still more numerous and more regular, and the anterior area has become more extensively developed.

I. lamarcki, Park. (zone of *Rh. cuvieri* to zone of *M. cor-anguinum*), shows a great amount of variation. An early form has nearly equal valves and only slightly developed concentric folds, and approaches closely *I. pictus*, from which it is believed to have been derived.

I. involutus, Sow. (zones of *M. cor-testudinarium* and *M. cor-anguinum*), is linked by intermediate forms with the variety of *I. lamarcki*, which has a very convex left valve and prominent umbo. In the intermediate forms the left valve loses its folds and develops a large, spirally-coiled umbo; the right valve becomes less convex and gradually loses its anterior area, but retains the strong concentric folds.

I. cordiformis, Sow. (zone of *M. cor-testudinarium* to *Uintacrinus* Band), has been derived from a variety of *I. lamarcki*, with inflated and nearly equal valves, by the development of one or two radial sulci and a relatively longer hinge.

I. costellatus, Woods [1] (Chalk Rock), appears to have come from an early form of *I. lamarcki* by the axis of growth becoming more oblique to the hinge and by the development of a more pointed umbo.

I. subcardissoides, Schlüt., *I. digitatus*, Sow., *I. pinniformis*, Will., and *I. corrugatus*, Woods,[2] are allied one to the other, and appear to have arisen from the less convex forms of *I. lamarcki* by the development of radial folds such as occur occasionally in *I. lamarcki* and allied species.

B. *I. crippsi*, Mant. (Upper Greensand to zone of *H. subglobosus*), agrees in many respects with the form of *I. anglicus*, which has fewer and less regular ribs, but in this species the hinge has become somewhat shorter, the postero-dorsal part of the shell less compressed, the anterior area smaller, and the ribs fewer and more irregular with a less strongly marked posterior curvature.

In *I. crippsi*, var. *reachensis*, Eth. (Chalk Marl to zone of *H. subglobosus*), the shell has become relatively higher and the posterior curvature of the ribs greater: this variety resembles closely the small forms of *I. labiatus* (Schloth.) (zones of *Rh. cuvieri* and *T. lata*); but in later stages the shell in that species grows extensively in a direction oblique to the hinge, and thus acquires a mytiliform shape. In the zone of *Terebratulina lata* the specimens of *I. labiatus* are usually longer and less high than in the zone of *Rh. cuvieri*, and these pass into *I. labiatus*, var. *latus*, Sow. (*H. planus* zone).

I. inconstans, Woods [3] (zone of *H. planus* to zone of *B. mucronata*), undoubtedly belongs to the *labiatus* stock, and the nearly flat forms approach closely *I. labiatus*, var. *latus*, from which they have probably been derived.

I. balticus, Böhm (zone of *Marsupites* to zone of *B. mucronata*), possesses many of the characters of *I. inconstans*, from which it has developed by an increase in the length of the hinge.

I. lingua, Goldf. (zones of *Marsupites* and *A. quadratus*), is similar to the nearly flat forms of *I. inconstans*, but the shell has become higher. *I. lobatus*, Goldf. (zones of *Marsupites* and *A. quadratus*), is near to *I. lingua*, but has developed an angular ridge between the umbo and the postero-ventral extremity. *I. cardissoides*, Goldf. (zone of *A. quadratus*), and *I. tuberculatus*, Woods [4] (zone of *A. quadratus*), are closely related to *I. lobatus*.

I. undulato-plicatus, Röm. (Upper Chalk), resembles the nearly flat forms of *I. inconstans*, from which it appears to have been derived by the development of diverging radial folds.

[1] Q.J.G.S., vol. liii, pl. xxvii, figs. 14–17, 1897.
[2] Type, British Museum, L 22528.
[3] G. A. Mantell, *Foss. S. Downs*, pl. xxvii, fig. 9, and pl. xxviii, fig. 3, 1822; and F. Dixon, *Geology of Sussex*, pl. xxviii, fig. 29, 1850.
[4] Type in Dr. A. W. Rowe's collection, from Sewerby (Yorkshire).

December 6, 1911.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Faulted Inlier of Carboniferous Limestone at Upper Vobster (Somerset)." By Thomas Franklin Sibly, D.Sc., F.G.S.

The three small masses of Carboniferous Limestone at Luckington, Upper Vobster, and Tor Rock, Vobster, respectively, which lie in the overfolded Coal-measures of the southern portion of the East Somerset Coal-field, have been the subject of comment and speculation by many writers since two of them were first noticed by Buckland & Conybeare.

The Upper Vobster inlier is by far the largest of the three. Intermediate in position, it lies rather less than a mile to the north of the main outcrop of the Carboniferous Limestone of the Eastern Mendips. This inlier has been dissected to a remarkable extent by quarrying operations, and its structure is described in detail in the present paper.

The northern and eastern portions of the inlier are concealed by a thin covering of Lias, but its maximum width from north to south is probably little, if at all, greater than 400 yards, while the proved east-and-west extent of the Carboniferous Limestone is about 1,100 yards.

From personal observation, combined with important evidence recorded by previous investigators, the author has arrived at the following general conclusions:—

(1) The inlier is apparently a lenticular mass of Carboniferous Limestone, grits, and shales, superimposed upon the overfolded strata of the Coal-measures by powerful thrust movements.

(2) It comprises (*a*) a Northern Limestone Mass and (*b*) a Southern Limestone Mass, separated by (*c*) a Grit-and-Shale Mass.

(3) The beds of the Grit-and-Shale Mass are in faulted relation to the Carboniferous Limestone on both sides. On the northern side the immediately adjacent beds of limestone represent part of the *Seminula* Zone; on the southern side the adjacent beds belong to the Lower *Dibunophyllum* Zone. On both sides the limestones are locally distorted.

(4) In the Northern Limestone Mass, Vobster Quarry exposes over 500 feet of *Seminula* Beds, overfolded towards the north-west, and dipping south-eastwards at an angle of about 135°.

(5) In the Southern Limestone Mass, where portions of the Lower *Dibunophyllum* Zone and the Upper *Seminula* Zone are exposed, the strata are locally overfolded northwards.

(6) The beds of the Grit-and-Shale Mass comprise quartzites which must certainly be assigned to the Millstone Grit. They also include shales, with intercalated fine-grained sandstones, of considerable thickness. Possibly this mass includes the lowest beds of the Coal-measures, in addition to a portion of the Millstone Grit.

(7) In most of the sections of Carboniferous Limestone, signs of the immense stresses to which the strata have been subjected are very evident. The beds are often distorted, while slickensides and calcite veins are extensively developed on both a large and a small scale.

The occurrence of a Lamellibranch fauna at the top of the *Seminula* Zone is recorded as a feature of special interest.

2. "Geology of a Part of Costa Rica." By James Romanes, B.A., F.G.S.

The paper deals chiefly with that part of Costa Rica which lies to the west of San José as far as the Pacific coast. San José itself is situated in a wide valley sloping gently westwards, and drained by the Rio Grande and its tributaries (defined in the paper as the San José Valley). The northern boundary of this valley is the chain of recent volcanoes which rise gradually from its floor, while on the south the ground rises abruptly to form the Cerro Candelaria.

In this latter range of mountains are exposures of limestone, marl, etc., together with various igneous rocks. The limestone is that which is referred to the Cretaceous by R. T. Hill; but an examination of several exposures has failed to produce any Cretaceous fossils, while the occurrence in places of vast numbers of *Balani* points to a Tertiary age for the beds. As this limestone stretches right across the Atlantic–Pacific watershed between Cartago and San José, it yields clear evidence of an inter-oceanic connexion in this area in Tertiary times.

Of the igneous rocks, the most interesting feature is the presence of many boulders of monzonite, indicating a plutonic mass in these mountains. The surface of the San José Valley is composed of a thick series of andesitic lavas into which the rivers have cut deep gorges, exposing in some cases older river-deposits and buried spurs of the Cerro Candelaria. On the Pacific coast at Barranca and Manzanilla fossiliferous Tertiary beds are described. These are all marine ashes, and in the Manzanilla district appear to rest unconformably on an older limestone formation. From the same area a limburgite is recorded.

The dominant features of the Pacific shore-line are due to drowning, instead of to uplift as is the case on the Atlantic coast; these features have, however, been considerably modified by subsequent alluvial deposits.

The 'boulder-clays' of Costa Rica are shown in many cases to be normal river-deposits, though locally landslides and spheroidal weathering have played an important part. These deposits in the valley of the Rio Reventazon point to several distinct phases of river-action.

II.—Geologists' Association.

December 1, 1911.—Mr. William Hill, F.G.S., President, in the Chair.

Dr. A. Smith Woodward read a paper on a maxilla of *Triconodon ferox* discovered by Mr. John Newton in the Purbeck Beds of Swanage. The fossil was obtained from the 'Cap Stone', about 26 feet above the well-known Middle Purbeck mammal-bed, and just below the 'Feather', in which the only known jaw of *Triconodon major* was found. The fourth premolar and the three molars are perfectly preserved, and the third molar is shown to be reduced in size, with only two cusps.

OBITUARY.

SIR JOSEPH DALTON HOOKER,

O.M., G.C.S.I., M.D., D.C.L., LL.D., F.R.S., F.G.S., ETC.

BORN JUNE 30, 1817. DIED DECEMBER 10, 1911.

AT the advanced age of 94 there has passed away at his home, The Camp, Sunningdale, in Berkshire, the most eminent of British botanists. By extended observation in all quarters of the globe and prolonged research he threw light on many difficult problems in natural history, aiding and supporting Darwin and Lyell on the origin of species, and on the causes which have influenced the geographical distribution of plants and the production of insular floras. He was the second son of Sir William Jackson Hooker, who, born at Norwich, married the eldest daughter of Dawson Turner, F.R.S., botanist, antiquary, and also banker, of Great Yarmouth. Other daughters of Turner were married respectively to Sir Francis Palgrave, the Rev. John Gunn (Rector of Irstead, Norfolk), Bishop Jacobson of Chester, and T. Brightwen of Yarmouth. Having independent means Sir William Hooker settled at first at Halesworth in Suffolk, where his son Joseph was born. Afterwards he removed to Glasgow on being appointed Professor of Botany in the University, and subsequently he became Director of the Royal Gardens at Kew.

J. D. Hooker was educated at the High School and University at Glasgow, where he qualified as M.D. in 1839. He inherited his father's tastes for Natural History, and Botany in particular, and was fortunate in being appointed assistant-surgeon and naturalist on board H.M.S. *Erebus* in the great expedition conducted by Sir James Clark Ross to the Antarctic regions during the years 1839–43. The botanical observations made in the course of that voyage were published in six volumes (1844–60), and dealt with the plants of New Zealand and Tasmania, as well as those of Antarctic lands. The philosophic conclusions bearing on the causes of the geographical distribution of the plants were published in 1859, in a now classic memoir *On the Flora of Australia, its origin, affinities, and distribution, being an Introductory Essay to the Flora of Tasmania.*

In 1846 Hooker was appointed Botanist to the Geological Survey of Great Britain, under Sir Henry De la Beche. His attention was now directed to the plants of past ages, and in particular to those of the Coal-measures; and he published an essay *On the Vegetation of the Carboniferous Period, as compared with that of the present day*, and two more special papers on the structure of *Stigmaria* and of some Lepidostrobi (Mem. Geol. Surv., vol. ii, pt. ii, 1848).

In 1847 Hooker resigned his appointment on the Geological Survey for the purpose of studying the botany of India, spending the years 1847–51 mostly in the higher mountain regions of that country, and publishing the general results in his famous *Himalayan Journals* (two vols., 1854). Interesting observations were therein included on the delta of the Ganges, and on the parallel terraces in the Himalayas, the formation of which was attributed to the barring of glacier lakes by ice and moraines.

In 1855 Hooker was appointed Assistant Director of Kew Gardens, becoming Director on the death of his father in 1865. Meanwhile he made an expedition to Syria and Palestine in 1860, and apart from his special botanical work made observations on the moraines of extinct glaciers on which some of the ancient cedars of Lebanon grow. In later years he explored parts of Morocco and the Great Atlas in company with John Ball, F.R.S., and George Maw (1871), and visited the Rocky Mountains and California in 1877. In 1885 he resigned his Directorship of Kew Gardens. Hooker was elected a Fellow of the Geological Society in 1846, and served as a member of Council during the years 1852–6 and 1860–2. To that Society he contributed several papers on fossil plants. He became F.R.S. in 1847, and was President of the Royal Society and ex officio a Trustee of the British Museum from 1873 to 1878. In recognition of his distinguished services he received a Royal Medal in 1854, the Copley Medal in 1887, and the Darwin Medal in 1892. He was President of the British Association at the Norwich meeting in 1868. Hooker married (1) the daughter of the Rev. J. S. Henslow, and (2) the daughter of the Rev. W. S. Symonds (Rector of Pendock) and widow of Sir W. Jardine (7th Baronet).

After his retirement from Kew he continued to labour diligently at work connected with his favourite studies. He gave much time to the great *Index Kewensis*, which was prepared under his direction by Dr. B. Daydon Jackson; and he edited, with life of the author (1906), the *Journal of Sir Joseph Banks*, which was kept during Captain Cook's first voyage.

Sir Joseph Hooker was buried in the old churchyard at Kew on December 15. H. B. W.

ROBERT DAVIES ROBERTS, M.A., D.Sc., J.P., F.G.S.

Born 1851. Died November 14, 1911.

We regret to record the death of Dr. R. D. Roberts, who was Registrar of the Board for the Extension of University Teaching in the University of London. He was born at Aberystwith, educated at University College, London, and Clare College, Cambridge, where he took a high position in Natural Sciences, geology at the time claiming his chief attention. He was University Lecturer in Geology in 1884, and in 1893 published *An Introduction to Modern Geology*. During later years his time was given to more general educational work and administration. He was High Sheriff of Cardiganshire in 1902–3.

MISCELLANEOUS.

Flint Implements.—The *Morning Post* of December 26, 1911, devotes a column to "Flint Implements", "The Flint Collector", "Flints which are not genuine", and "The means by which to distinguish genuine implements from false ones". We fear so long as a clever and dishonest 'flint-knapper' lives and makes *good forgeries* there will always be found simple folks to buy them.

HOWE (J. A.). Geology of Building Stones. London, 1910. 8vo. With 8 plates. Cloth. 7*s.* 6*d.*

HYATT (A.). Pseudoceratites of the Cretaceous. Washington, Geol. Surv., 1903. 4to. pp. 351. With 47 plates. Cloth. 4*s.* 6*d.*

IRON ORE RESOURCES OF THE WORLD: Inquiry made upon the initiative of the Executive Committee of the Eleventh International Geological Congress, Stockholm, 1910, with the assistance of Geological Surveys and Mining Geology of different countries. Stockholm, 1910. 2 vols. of text. 4to. With 22 plates and 142 illustrations, and accompanied by an atlas in folio of 43 maps. £3.

JOHNSON (J. P.). The mineral industry of Rhodesia. London, 1911. 8vo. pp. 90, interleaved with blank paper for notes. Cloth. 8*s.* 6*d.*

——— The Pre-historic Period in South Africa. London, 1911. 4to. Illustrated. 10*s.*

JUDD (J. W.). The Student's Lyell; the principles and methods of geology, as applied to the investigation of the past history of the earth and its inhabitants. 2nd edition. London, 1911. 8vo. pp. 645. With portrait and 736 illustrations in the text. Cloth. 7*s.* 6*d.*

JUKES-BROWNE (A. J.). The Building of the British Isles: being a history of the construction and geographical evolution of the British region. 3rd edition. London, 1911. 8vo. Illustrated. Cloth. 12*s.*

KRAUS (E. H.) & HUNT (W. F.). Tables for the determination of Minerals by means of their physical properties, occurrences, and associates. New York, 1911. 8vo. pp. 254. Cloth. 8*s.* 6*d.*

LAKE (P.) & RASTALL (R. H.). Text-Book of Geology. London, 1910. 8vo. With 32 plates. Cloth. 16*s.*

LAUNAY (L. DE). La géologie et les richesses minérales de l'Asie: Historique—Industrie—Production—Avenir—Métallogénie. Paris, 1911. Roy. 8vo. With very numerous illustrations. Cloth. £1 8*s.*

LEMOINE (P.). Géologie du Bassin de Paris. Paris, 1911. 8vo. Ouvrage enrichi de 136 figures et 9 planches hors texte. Cloth. 12*s.*

MOORHEAD (W. K.). The Stone Age in North America. London, 1911. 2 vols. 4to. Cloth. £1 11*s.* 6*d.*

NICKLES (J.). Bibliography of North American Geology for 1909. With Subject Index. Washington, 1911. 8vo. pp. 174. 2*s.*

ROWE (J. B.). Practical Mineralogy simplified. London, 1911. Roy. 8vo. 5*s.* 6*d.*

RUEDEMANN (R.). Graptolites of New York. Albany, State Museum, 1904–8. 2 vols. 4to. With 48 plates. Cloth. £1.

SCHWARZ (E. H. L.). Causal Geology. London, 1910. 8vo. Illust. Cloth. 7*s.* 6*d.*

SMITH (P.). Geology and Mineral Resources of the Solomon and Casadepaga Quadrangles, Seward Peninsula, Alaska. Washington, 1911. 8vo. pp. 234. Illustrated. 4*s.*

TEALL (J. J. HARRIS). British Petrography: with Special Reference to the Igneous Rocks. 1888. Roy. 8vo. 458 pp. of text, with 47 plates, some coloured, bound in cloth extra, gilt top. £3 3*s.* net.

TUTTON (A. E. H.). Crystallography and Measurement. London, 1911. 8vo. pp. 960. Cloth. £1 10*s.*

WATSON (J.). British and Foreign Building Stones: a descriptive catalogue of the specimens in the Sedgwick Museum, Cambridge. Cambridge, 1911. 8vo. Cloth. 3*s.*

WATSON (T. L.). Granites of the South-Eastern Atlantic States. Washington, 1910. 8vo. 5*s.*

THE SUBANTARCTIC ISLANDS OF NEW ZEALAND. Reports on the Geophysics, Geology, Zoology, and Botany of the Islands lying to the South of New Zealand. Based mainly on observations and collections made during an expedition in the Government steamer *Hinemoa* (Captain J. Bollons) in November, 1907. Edited by CHAS. CHILTON, M.A., D.Sc., F.L.S., Professor of Biology, Canterbury College, University of New Zealand. Profusely illustrated with full-page plates, photographs, and text-figures, and a large map of the Antarctic and Subantarctic Regions specially compiled and based on the most recent surveys. In two volumes, demy 4to, of about 400 pages each, 42*s.* net.

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HENRY WOODWARD, LL.D., F.R.S., F.G.S., &c.

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FEBRUARY, 1912.

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LONDON: DULAU & CO., LTD., 37 SOHO SQUARE, W.

PROFESSOR A. E. TÖRNEBOHM,

For. Corr. Geol. Soc. Lond., Director Geological Survey of Sweden 1897–1906.

Born October 16, 1838. Died April 21, 1911.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. II.—FEBRUARY, 1912.

ORIGINAL ARTICLES.

I.—Some Account of the Geological Work of the late Professor A. E. Törnebohm.[1]

By A. G. Högbom, Professor of Geology in the University of Upsala.

(WITH A PORTRAIT, PLATE III.)

As already mentioned in this Magazine (September, 1911), the Swedish geologist, Professor Alfred Elis Törnebohm, died on April 21, 1911, at the age of 72.

Professor Törnebohm's name is chiefly renowned in the scientific world for an audacious theory in which he postulates an enormous overthrust as governing the tectonics of the Scandinavian mountain range. But his contributions to geological science in other respects are also important enough to give him a distinguished place among his contemporaries. His interest, outside of the geology of the mountain range, was mainly engaged in microscopic petrography and in deciphering the ore-bearing Archæan districts of his country.

Professor Törnebohm was held in general esteem alike for his important scientific works and for his sterling personal qualities. It was, therefore, a great disappointment to his Swedish colleagues that failing health rendered it impossible for him to take a more active part in the geological congress held in Stockholm in 1910.

A short account of Professor Törnebohm's life and a summary of his more important works have been asked for by the Editors of this Magazine, and thus a precious opportunity is afforded to one who, as a younger colleague, has worked in the same fields of research.

A. E. Törnebohm was born in Stockholm on October 16, 1838. In his school and college days he was much interested in chemical and physical experiments; scholarships and fellowships attracted him but slightly. Having in the years 1855–8 passed through the Technical High School of Stockholm, he spent a year in the State Printing Office of Vienna in Austria, there mainly studying galvanoplastic methods of reproduction, allied to the more modern collotype process. His close acquaintance with these methods was of value to him in publishing his geological maps later on.

After his return to Sweden (1859) Törnebohm entered the newly established Geological Survey as State Geologist, and worked there

[1] Professor of Mineralogy at the Technical College, Stockholm, 1878–97, and Director of the Geological Survey of Sweden, 1897–1906. For. Corr. Geol. Soc. Lond., 1910.

until 1873. Several maps (1 : 50,000), with descriptions, were published during these years. Noteworthy among them are the sheets comprising a great part of the Pre-Cambrian complex, generally known as the Dal Formation, which lies west of Lake Wenern. Beneath this Dal Formation, and separated from it by a great unconformity, comes an Archæan complex, the Amal Complex, in which Törnebohm, as far back as 1870, recognized volcanic tuffs and beds of conglomerate; the latter are probably the first described true Archæan conglomerates.

Besides mapping in different parts of Middle Sweden, Törnebohm at this stage of his career entered the highlands and dealt with their stratigraphy in two important memoirs. The first of these memoirs gave a cross section of the mountain range from Ostersund to Levanger (1872), and the second, *Über die Geognosie des Schwedischen Hochgebirges* (1873), was accompanied by a survey map of a considerable part of the highlands. In these papers Törnebohm stated that the fossiliferous Cambrian and Silurian rocks at the eastern border of the mountain range were covered by thick complexes of mica-schists, gneisses, amphibolites, and quartzites. The stratigraphy was regarded as normal and the rock complexes were divided up into a lower series, the Seve Group, and an upper series, the Köli Group, both regarded as younger than the underlying fossiliferous Silurian. Some geologists in Sweden opposed this interpretation, and in Norway the researches of Kjerulf could not be brought into harmony with it. On the other hand, later surveys reaffirmed the general correctness of Törnebohm's observations in regard, that is, to the order of superposition of the strata in the districts examined by himself.

But Törnebohm had no opportunity to pursue his researches in the mountains for some years to come. In 1873 he left his post as State Geologist, and partly for purposes of study, partly for considerations of health, undertook a journey to Italy, Austria, and Germany. He stayed for a time in Leipzig, where, under the guidance of Professor Zirkel, he learned microscopic petrography.

After his return home Törnebohm surveyed several mining districts in Middle Sweden, and in 1878 was appointed Professor of Mineralogy and Geology at the Technical High School of Stockholm; this post, in 1897, he exchanged for the directorship of the Geological Survey.

In the seventies and eighties Törnebohm published a great number of petrographical memoirs, as, for instance, his fundamental *Systematic Research on the Diabases and Gabbros* (1877), and his descriptions of zircon, epidote, scapolite, and calcite as constituents of igneous rocks. He also examined several rock types, new to science, namely, cancrinite-syenite, alnöite, and somewhat later (1907) catapleite-syenite, with associated rocks. His study *Zur Petrographie des Portlandscements* (1905) attracted much attention.

Besides these purely petrographical papers, Törnebohm has left rich material of a similar character in the form of petrographical observations dispersed through his more strictly geological works. For theoretical problems of petrology he had but little interest, and accordingly did not enter much into such matters. The breadth of his researches in petrography is illustrated not only by his writings, but also by his fine collection of four thousand slides, all made by himself. The grinding and preparation of these slides was for him a daily gymnastic exercise, which he did not like to neglect. It gave him great pleasure to demonstrate to his colleagues new slides showing features of interest.

Petrography was for him, however, more or less an incidental occupation or else a means to an end in his profound researches into Archæan geology. Apart from a series of smaller memoirs dealing with the Archæan, Törnebohm published (1882) his monumental "Map of the Ore-bearing Archæan in Middle Sweden" (*Hellersa Sveriges Bergslag*), on the scale 1 : 250.000. The views set forth by Törnebohm in the text accompanying this map as to the genesis of the Archæan rocks and ores may be, in essential parts, antiquated; but even when regarded from the present standpoint of science, the map promises to maintain its position for a long time as a most important primary source of knowledge in regard to this exceedingly interesting Archæan district. In addition Törnebohm made several ore-fields, included in this same district, as Dannemora, Norberg, Persberg, and Falun, the subjects of more detailed individual treatment, and he also described other mining districts situated elsewhere in the great North European Archæan. Among these may be mentioned the copper-mine district of Atvidaberg-Bersbo, the renowned iron mountain Taberg, south of Lake Vettern, and the Pitkäranta mines in Finland.

Having accomplished the great map of Middle Sweden, Törnebohm resumed his researches in the mountain range. During the ten years that had passed away since he had published his first memoirs about the geology of the highlands, the knowledge of the stratigraphy of the district had but slightly advanced; Törnebohm, however, was fully aware that difficulties met his old interpretation, and that a review of the whole evidence and a correlation of the Swedish and Norwegian parts of the mountain range were necessary. Hardly, however, could he have imagined that he would spend so much as thirteen summers of laborious surveying before he could reach a satisfactory theory of the tectonics!

With admirable perseverance Törnebohm roamed through the barren highlands in all directions, often returning to critical localities, where new suggestions led him to reconsider his old ideas and working hypotheses. It has been told that sometimes his assistants ran away from him because they could not endure the fatigues or follow him when with his great strides he rambled over the mountains. Törnebohm needed but a slight equipment for his personal comfort. Some handfuls of raisins and almonds were often his provisions for a hard working day in the field. The desolateness of the country, want of topographic maps, absence of fossils, sudden change in the facies of the rock-groups, and varying stages in their metamorphism combined to render geological surveying exceedingly difficult. At the present day, thanks to the pioneer work of Törnebohm and to all the added advantages of good topographic maps and developed means of intercourse, students of a younger generation can easily appreciate the main features of the geology, and they can hardly imagine the difficulties which met the first explorations in these mountain ranges.

This is not the place for a detailed account of the development of highland geology in Sweden; the stages passed through were much the same as in the interpretation of the North-West Highlands of Scotland. It need only be recalled that Törnebohm's first conception of the Seve and Köli Groups as younger than the Silurian could no longer be maintained, since Silurian fossils were discovered in the Köli Schists. In a paper entitled "Om fjellproblemet" ("The Problem of the Highlands"), published 1888, Törnebohm first advanced his hypothesis of a great overthrust: the Pre-Cambrian Seve Group, with the superimposed Köli Schists, he now interpreted as having been thrust eastwards some tens of miles, and in this wise superimposed upon the fossiliferous Cambrian and Silurian areas in the east. The Köli Schists, which have their richest development on the Norwegian side, he regarded as an anomalous facies of the Cambrian and Silurian, differing from the more normal development of these systems, not only through their more or less pronounced metamorphism, but also through their admixture with abundant igneous rocks. Relying upon several discoveries of fossils and on the tectonics, Törnebohm divided up the Köli Schists into a series of subdivisions which may here be passed over. The final result of his extensive researches he published (1896) in the memoir *Grunddragen af det centrala Skandinaviens geologi* (*The Outlines of the Geology of Central Scandinavia*). The memoir is accompanied by a map, on the scale 1 : 800,000, comprising an area of not less than 36,000 square miles.

By travelling in parts of the Scandinavian chain other than those dealt with in the two publications cited above, Törnebohm moreover got a general view of its geology, and was thereby enabled to apply his thrust-theory to the mountain range in its whole extent. This he has done on the maps in his textbooks of geology and on his great wall-map of North Europe.

Several geologists in Sweden, as well as in Norway, are still unconvinced in regard to the great thrusts; none of them, however, has been able to produce a map which can satisfy in any other way the tectonic relations. Admittedly the last word has not yet been said about the mountain tectonics of Scandinavia, but there is every probability that the great lines have been rightly traced by Törnebohm, and that the further development of our knowledge must proceed from the basis laid down by him. The next objects for research will probably be the inner composition and structure of the great thrust-masses, the minor thrusts occurring in them, and the rôle played by the intermixed igneous rocks. Furthermore, the stratigraphy of the great sparagmite complexes needs thorough revision.

Törnebohm's field of research, mountain tectonics and the Archæan, offered a wide scope for subjective views. With the divining rod of his intuitive faculty he often has found the right interpretation where a more wary geologist, considering the lack of information, would have refrained from a definite opinion. His precision of aim was admirable, but he was not safe from great errors. In scientific discussion he was hardly open to conviction. Facts that did not harmonize with his views impressed him but little before he could verify them for himself in the field. In debate he was, therefore, often a fierce adversary, who made his opponents feel the whole gravity of his authority. But after a strong conflict his soulful eyes again beamed with their usual kindness.

Törnebohm had other interests besides geological, and he was much impressed by spiritualistic and theosophic ideas; in his library literature dealing with these subjects was well represented, but he did not feel inclined to visit spiritualistic conferences or circles; for that he was of too solitary a nature. As a rule he was reticent upon the subject, but some few months before his death he wrote a paper in which he set forth his ideas on transcendental phenomena and vindicated an idealistic standpoint against the materialistic views especially prevalent in popular scientific literature. He expresses here his agreement in these matters with the English physicist F. W. Barret.

Though apparently almost indifferent to popularity and external distinctions, Törnebohm, especially in the last years of his life, much appreciated testimonies of esteem from his Swedish and foreign colleagues. He was, without question, delighted by the honour accorded to him by the Geological Society of London in making him a Corresponding Member (1910).

Having left the directorship of the Geological Survey in 1907, Törnebohm settled in the small idyllic town Strengnäs on the shores of Lake Mälar. Here he retired much from geology. He said that as he had no further opportunity of working in the field or of following the literature he had sense enough to keep silent. Notwithstanding, some small geological papers still appeared. One of his last writings, dating from 1909, describes Pre-Cambrian fossils, found by him in the Dal Formation and in the Norwegian Sparagmite Formation. These fossils have since been identified by Professor Rothpletz in Münich as calcareous algæ.

Sailing, cycling, carpentry, and turnery diverted him towards the end of his life, until the growing infirmities of old age (arteriosclerosis) made an end of such recreations.

Professor Törnebohm was married in 1897, and left a widow but no children.

In Geol. Fören. Förhandl., Stockholm, Bd. xxxiv (1912), a fuller biography of Professor Törnebohm will shortly appear, with a complete list of his published works. Since Professor Törnebohm has written almost all his works in Swedish it may be useful to add that his more important memoirs about the Archæan and the thrust-region have been reviewed and referred to in the author's papers, "Pre-Cambrian Geology of Sweden" (Bull. Geol. Inst. Upsala, vol. x, 1910) and "Studies in the Post-Silurian Thrust-region of Jämtland" (Geol. Fören. Förhandl., Bd. xxxi, 1909), both published in English.

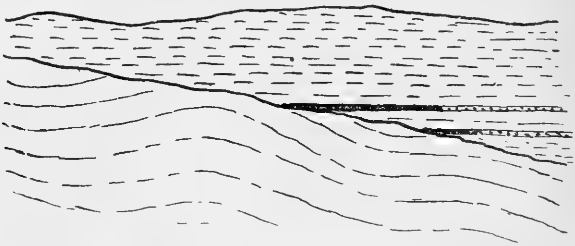
II.—Outlines of Oilfield Geology.

By T. O. Bosworth, B.A., B.Sc., F.G.S.

(*Concluded from the January Number, p. 23.*)

8. *Arenaceous Strata unconformable on an Oil-generating Formation.*—Occasionally a formation, though a parent source of petroleum, does not contain porous rocks suitable for oil accumulation. But a second formation resting unconformably upon the first may be admirably

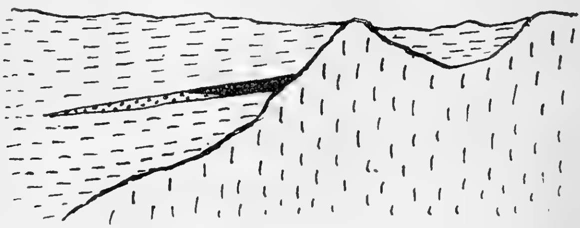
situated for receiving and storing the oil, for this second formation probably contains the necessary sandstones, and also all the unconformable strata are likely to be more or less arnaceous where they abut against the plane of unconformity, thus facilitating the transfer of the oil from the rocks below (Fig. 9). Cases of this kind occur in California in the Coalinga Oilfield, where oil is obtained from sandstones in the Miocene which lies unconformably over the Eocene; also in Roumania, where the Meotic formation transgresses over the Saliferous.



Oil-generating Strata.

Fig. 9. Oil accumulation in porous strata unconformable on oil-generating strata.

9. *Strata tipping unconformably from an old Shore-line.*—This is supposed to be the case in the Maikop Field, the oil having accumulated in more or less lenticular sands abutting against a shore-line of Cretaceous rocks. Such conditions are favourable to accumulation, for the porous beds are gently inclined and are sealed up at their upper ends (Fig. 10).



Cretaceous.

Fig. 10. Oil accumulation in strata tipping unconformably from an old shore-line.

10. *Exceptional Circumstance.*—Occasionally large quantities of oil are obtained from fissures, fault-planes, planes of unconformity, cavities, etc.

B. Oil Accumulations depending on Denudation.—Outcropping petroliferous strata have been referred to by practical men as 'monoclines' in contradistinction to anticlines, which at one time were thought essential for the accumulation of oil. These 'monoclines' are often really limbs of denuded anticlines, and the term would be applied to several of the cases already described and to all cases where the oil-rocks crop out. Most of the gas and much of the lighter constituents of the oil have generally escaped from outcropping oil-rocks, though under certain circumstances valuable accumulations are found. But oil-sands outcropping far from the anticlinal axis seldom contain much oil.

1. *Oil-sands sealed at Outcrop by Bitumen.*—The escaping oil on evaporation has often left behind oxidized residues which block up the pores of the oil-sand and prevent the escape of the remaining oil.

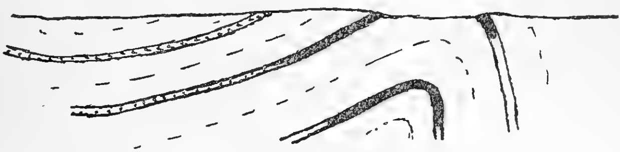


FIG. 11. Oil in outcropping beds, near anticline, sealed in by bituminous residues.

Large quantities of oil are obtained from such outcropping rocks in many oilfields by drilling to strike them at depth, but the yield per well usually is not great, because owing to the gas having escaped there is but little pressure (Fig. 11).

2. *Oil-sand Sealed at Outcrop by Infiltrated Mineral Matter.*—Surface-waters bearing calcium carbonate or other mineral matter sometimes have deposited cement in the pores of an outcropping sandstone and thus stopped the escape of the oil ascending towards the outcrop.

C. OIL ACCUMULATIONS DETERMINED BY PETROGRAPHICAL CIRCUMSTANCES.—When the rocks are not appreciably folded or denuded the characters of the rocks have been the chief factor in determining the sites of oil-pools.

FIG. 12. Oil accumulation in horizontal sand lenticle. Length of section, say 1 mile.

1. *In Lenticles.*—In undisturbed strata big lenticles of sandstone, with impervious clay above, are ideal places for the accumulation of oil (Fig. 12). Being convex they possess much the same advantage as a dome, for the hydrocarbons moving upwards are trapped and concentrated under the apex of the dome-shaped clay roof. Good examples occur in the Oklahoma Oilfields.[1]

[1] "The Origin of Oil and Gas," by L. L. Hutchinson: *Petroleum Review* June 3, 1911.

2. *Discontinuous inclined Porous Beds.*—Where a porous band thins out, becomes fine-grained, or otherwise loses its porosity before reaching outcrop, gas and oil may accumulate at the upper limit (oil at the lower limit if the rock be dry). Examples are known in the Oklahoma and Coalinga Oilfields (Fig. 13), and probably are very common.

3. *Pools resulting from differences in Capillarity and Porosity.*—Over large tracts in the United States where oil is mined from strata situated at great depth and almost undisturbed, e.g. parts of the Appalachian Oilfields, oil is distributed sporadically in isolated pools. The pools are discovered and their limits proved by trial; generally they occur in the most porous parts of highly porous rocks. Probably

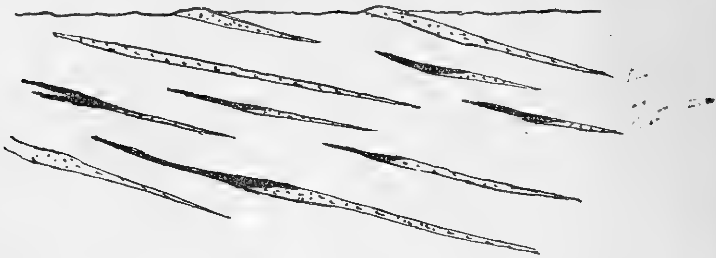


FIG. 13. Oil in inclined discontinuous porous beds, as in Coalinga Field. Length of section, say 1 mile.

many of these pools of oil have been driven into their present position [1] by the complicated movements of waters circulating under the guidance of capillary attraction—a force which would vary greatly in different beds, and from place to place in each bed, according to texture, cement, current-bedding, etc.

PART III. SURFACE PHENOMENA OF DECARBONIZATION PROCESS.

The visible indications of this natural process will now be briefly enumerated.

Oil-sands at Outcrop.—At outcrop oil-sands, though they have a pitchy smell, are seldom visibly moist with oil, for on evaporation oxidized residues fill up the pores of the rock. Most common are the oils having an asphaltic base, in which case the bituminous residue is very dark, giving the rock a deep-brown or black appearance. Although an outcropping oil-rock is generally dark and dry, it is often possible with the pick to break far enough into it to find it oily and of a lighter colour. In coast-sections oil-rocks washed by the tides often present this appearance, and sometimes are so soft and sticky that drops of oil may be squeezed out by hand. In strata containing light oil with a paraffin base, however, evaporation may be so complete as to leave little or no indication of petroleum at the outcrop. If, however, the outcropping oil-sands be broken with the hammer, the oil often may be detected by smell, or if water be present, by the oil film which spreads over its surface.

[1] M. J. Munn, "Theories of Gas and Oil Accumulation," *Economic Geology*, 1909, p. 509; also "Anticlinal and Hydraulic Theories", *Petroleum Review*, January, 1910.

Oily Clays.—The exposed clays of a petroliferous formation do not so readily lose their hydrocarbons, and often they are found to smell of oil quite strongly, even where exposed at the surface.

Burnt Clays.—Occasionally, as in Trinidad and California, there occur beds of clay-shale, sometimes 10 feet or more in thickness, which have been naturally burned (at depth) into hard red rock like brick by the combustion of the bituminous material contained in them.

Oil Seepages.—Oil exuding from outcropping oil-sands, or coming up faults and joint-cracks, frequently seeps through the surface soil, forming pools which are sometimes of considerable size.

Likewise films of oil are often seen on the surface of water in swamps, wells, and springs. The surface of the sea is sometimes similarly overspread for miles.

Pitch.—Pitch is one of the commonest indications of oil. Extensive deposits occur in Mexico, California, Venezuela, Trinidad, West Africa, Borneo, Russia, etc. The composition of the pitch depends on that of the oil it is derived from, and also varies according to the extent to which evaporation and oxidation have advanced. Many oil-sands near the surface contain sticky pitch, and spreads of pitch mixed with sand often cover the outcrops and occupy the bottoms of ravines into which they have flowed. Generally the pitch appears on the surface as numerous cones, isolated or in groups. Usually the cones are only a few feet or less in height, but in some places there are pitch hills of 50 feet or more. Single cones are symmetrical, and on the outside may be hard and dry, but at the apex is a little crater from which flow takes place. When cut open it is seen that the cone is built upon the surface soil above some crevice, up which soft sticky pitch and thick heavy oil is slowly ascending through the ground, and thence up the central pipe of the cone to the apex.

In country covered with thick vegetation the outcrops of oil-sands can be traced by the occurrence of pitch and the approximate course of an anticline may be followed for miles. Pitch also occurs at submarine outcrops, for soft fresh pats of pitch are washed up ashore abundantly on the coast of petroliferous country. The extensive deposits of pitch at present on the earth's surface bear witness to the immense quantities of petroleum which have escaped into the atmosphere in recent times.

The best known individual and uninterrupted pitch spread in the world is the Trinidad Pitch Lake with an area of about a quarter of a square mile, but there are more extensive areas covered with pitch in Venezuela. Estimating the total contents of the Pitch Lake at ten million tons, it follows that some forty million tons of oil must have evaporated at that one site alone.

Bitumen in Fissures. — Fault fissures, joint-cracks, and cavities among rocks above or associated with petroliferous strata, are sometimes filled with bitumen derived from the oil. The bitumens derived from asphaltic oils differ from the pitch which is formed from the same oil at the surface, being hard, black, lustrous substances which break with conchoidal fracture. One of the best known of the many different kinds is manjak, which is mined in Trinidad and Barbadoes.

Limestones, sandstones, and conglomerates are often heavily charged with asphaltic bitumen.

The bitumens derived from paraffin oils are soft waxy substances of pale colour, the most important being ozokerite, which is mined in the strata overlying the oil rocks at Boryslav in the Galician Oilfield, and also occurs in quantity on the island of Cheleken. This ozokerite occurs in fissures sometimes as lumps and cakes weighing several pounds, but the main production is obtained on treating the clay shales with hot water.

Gas.—Exudations of gas are numerous in most oilfields, ascending through the surface soil from outcrops and fractures. Generally they can be detected by the smell, and often also they can be ignited and may burn continuously. In wet ground the noise of the gas bubbling up through pools of water assists detection. Occasionally violent outbursts have been known to blow out cavities in the rocks.

Sulphur.—Sulphuretted hydrogen and sulphur-dioxide frequently accompany the escaping gas, and deposits of sulphur in cracks in the rocks or on the surface are not uncommon indications of hydrocarbons below.

Sandstones in Peru, and thick limestones in Texas and Louisiana, are impregnated with sulphur to such an extent that when they are heated melted sulphur runs out. Hot sulphurous springs of water are of frequent occurrence in oil territory, and often when a well approaches exhaustion sulphur water ascends.

Salt.—The complete relationship between salt and petroleum is not understood, but it is a conspicuous fact that salt is nearly always in some way associated with petroleum either as crystalline masses of rock-salt, or salt water, or saliferous strata. It is true that the conditions favourable for the preservation and storage of hydrocarbons are also those favourable for the presence of bodies of imprisoned sedimentation water, but the salt water which accompanies petroleum is usually much more saline than the water normally present at depth in sedimentary rocks, and suggests some further relationship.

Mud Volcanoes.—These occur in almost all parts of the world where oil-rocks approach the surface. They are built up over springs which exude mud, gas, and hot water often with a little oil. Sometimes mud volcanoes form hills a hundred feet or even several hundred feet high, but most numerous are small cones rising only a few feet. Common also where much water accompanies the mud are volcanoes of larger area and very slight elevation. A typical example observed by the writer in Trinidad had a soft mud crater of 35 yards diameter, in the middle of which was a salt pool 12 yards across.

The noise of the great gas bubbles, which burst up every minute or two, could be heard two or three hundred yards away. The soft mud was surrounded by harder mud on which one might cautiously walk, the whole volcano forming a nearly flat, bare mud patch of 100 yards diameter, in the midst of thick forest. The volcano was surrounded by a little moat into which streams flowed from the crater. Outside this, sandy ground rose 5 or 10 feet, but was cut through in one place by a miniature gorge where the muddy salt water found egress from the moat as the source of a stream.

Sometimes mud volcanoes act with such violence as to throw up tons of clay and rock 20 or 30 feet into the air, and in two known instances small islands, hundreds of feet across, have been built up off the coast by submarine mud volcanoes situated on well-known anticlines.[1] Mud volcanoes occur chiefly along the crests of anticlines or along fault lines.

Conclusion.

Petroleum or other bituminous matter is common in small quantity in sedimentary rocks of all ages, and in certain cases where the structure is favourable it is present in large amounts.

Some idea of the quantities of oil found imprisoned in the earth's crust is obtained from a study of oilfields' statistics. The world's annual output during the last few years has exceeded 40 million tons, whilst from only 6 square miles of country near Baku 11 million tons of oil were extracted in one year, and it is estimated that the oil which has been obtained from one 27 acre property there would fill a tank of that area to a depth of 270 feet.[2] In a number of instances in various parts of the world the amount of oil yielded in one year by a single well has exceeded 100,000 tons. At the present time immense quantities of petroleum oil and gas are escaping naturally at the earth's surface almost wherever Tertiary strata have been upraised and exposed to denudation. This is a natural process of decarbonization; shallow-water sediments which probably have formed the main bulk of the marine deposits of every age originally contain a great amount of carbonaceous material disseminated in their muds, and this carbon is capable of undergoing chemical change into volatile hydrocarbons, which must be eliminated ere the composition of the rocks is stable.

Thus we do not now commonly find oil in the older rocks, except where they have been deeply buried and sealed up by newer formations practically undisturbed. Under such circumstances occur vast stores of oil in the Silurian, Ordovician, Devonian, and Carboniferous formations in the Appalachian fields of the United States. But in the majority of oilfields the oil-rocks are of Tertiary age.

The decarbonization of the freshly upraised Tertiary sediments is taking place in the earliest stage of their denudation, and long ere the next marine transgression has overlaid the area with new permanent deposits, it is likely that further denudation will have entirely obliterated all records of the process, leaving in the Tertiary as little indication of petroleum as in the old formations now. It is therefore not improbable that the older formations were as petroliferous as the Tertiary, and that the decarbonization process at present witnessed on the surface of the newly upraised sediments has been usual on similar occasions in the past; or, in other words, many of the old planes of discordance have been the scenes of phenomena similar to those described above.

[1] A. Beeby Thompson, *Petroleum Mining*, 1910, pp. 102, 103.
[2] Ibid., p. 86.

III.—The Tachylite of the Cleveland Dyke.

By Miss M. K. Heslop, M.Sc., and R. C. Burton, B.Sc., F.G.S.

(PLATE IV.)

THE Cleveland Dyke is well exposed low down on the left bank of the River Tees, near the junction of this river and the Lune, being washed at flood-times by the water. It trends in a direction north of west, and can be traced for a distance of several hundred yards: its thickness is difficult to estimate as the north edge is covered by drift. The tachylite variety of the rock is only exposed for a few yards, and has only been found at this point—about 100 yards west of the junction of the Lune and Tees. The dyke here appears to occur in sheets very like successive lava-flows, and during cooling a columnar structure has been developed and the bases of the columns, mostly hexagons, face the river. The Cleveland Dyke at this exposure is represented by three varieties of rock—

1. Ordinary porphyritic rock.
2. Amygdaloidal porphyritic rock.
3. Stony rock associated with tachylite.

It is with the third variety that this paper is concerned. The stony rock occurs as a layer $1\frac{1}{2}$ feet thick, dipping 10° E.S.E. at a point just opposite the junction of the two rivers, while a few feet higher up the Tees the dip changes to 10° W.N.W.; above and underneath it the ordinary variety of the dyke occurs, and the junctions are quite as sharp as between successive lava-flows.

The true tachylite occurs as a selvedge $\frac{1}{8}$–$\frac{1}{4}$ inch thick, covering the stony rock on its southern face for a distance of several yards, and also seems to occur as veins in this variety. The latter mode of occurrence is remarkable, and suggests that just before consolidation part of the magma on the extreme edge of the dyke was injected into cracks in the very viscous layer adjacent to it, the temperature of which was low enough not to interfere with the almost immediate consolidation of the injected material as tachylite. This explanation, however, is put forward with a considerable amount of hesitation. In some parts of the exposure the stony rock forms an inner selvedge about 4 inches thick, while the tachylite covers this as a thin outer selvedge.

A few yards higher up the river there is an overflow of the dyke to the south. A black shale is found lying horizontally underneath the dyke for a distance of 11 yards; we could not determine whether the shale was greatly baked or not as the river water has softened the rock and altered it; the junction of the shale and the dyke is also difficult of access. This fragmentary section is, however, sufficient to point to the existence of a small overflow to the south, and this conclusion is supported by the occurrence of the igneous rock in sheet-like form, where the tachylite is found; lower down the river the ordinary dyke-form is resumed. The actual extent of the overflow, as seen, is 11 yards, but it is probably exposed over a greater distance. Its existence is interesting as it seems to prove that, for some reason possibly connected with the hade of the dyke, the injection of the molten magma has taken place with particular force to the south;

other overflows are known at Bolam and Buckheads, near Bishop Auckland, and have both taken place pre-eminently to the south.

As seen in the hand-specimens the tachylite is a hard black rock with a vitreous lustre, weathering to greyish on the surface. This colour change due to weathering is also well shown under the microscope, the tachylite becoming lighter near the devitrification cracks. The glass was infusible in the Bunsen flames, but with the blowpipe a black globule was formed, the fusibility lying between two and three on the scale. The specific gravity from several determinations is 2·60, while that of the ordinary variety of the Cleveland Dyke lies between 2·63 and 2·788.[1] The hardness was found to be 5·5. On treating some of the substance with hydrochloric acid to get rid of superficial iron-oxide, it was partly bleached on the surface to a greyish colour; this was thought to point to the existence of free magnetite, but the tachylite proved to be non-magnetic, being absolutely without effect on even the most sensitive mirror-galvanometer. Some of the tachylite, when treated with acid, seems to be heterogeneous, part being jet-black and part greyish-yellow; the latter probably due to a slight devitrification and decomposition with formation of chlorite.

The black variety was carefully sorted out and used for analysis. The methods used were those described by Hillebrand in Bulletin No. 422, Geological Survey, U.S.A. The results are recorded below, together with the analyses of the ordinary variety of the dyke, of the glassy groundmass as determined by Stock, and of the tachylite from the Western Isles of Scotland.[2]

	Tachylite of the Cleveland Dyke.	Normal variety of the Cleveland Dyke.	Glassy base of groundmass of Cleveland Dyke.	A tachylite from the Western Isles of Scotland.
H_2O	1·55	1·55	—	3·50
CO_2	3·64	3·60		
SiO_2	55·19	56·10	70·76	56·05
MnO	0·63	—	—	traces
CaO	7·53	11·20	3·29	6·66
MgO	4·12	2·29	4·21	1·52
Fe_2O_3	10·23	4·76	3·59	10·30
Al_2O_3	12·30	17·24	10·93	17·13
TiO_2	1·03	—	—	—
Na_2O	2·13	2·04	7·22	3·29
K_2O	1·30	1·38		0·98
	99·65	100·16	100·00	99·43

The composition of the tachylite is seen to correspond closely with that of the ordinary variety of the dyke—the similarity is yet more noticeable if other analyses of the dyke are considered. The particular analysis given was chosen because its percentages of water and carbon dioxide are the same as those in the tachylite. The silica percentage

J. J. H. Teall, "On the North of England Dykes": Q.J.G.S., vol. xl.
Judd & Cole, Q.J.G.S., vol. xxxix.

in the glassy rock is slightly lower—further analyses would probably give a slightly higher figure; the sum of the lime and magnesia is somewhat lower, while the sum of the oxides of iron, aluminium, and titanium is higher than in the ordinary variety of the dykes, and the alkalies are practically identical.

These results, then, agree with the evidence as to the identity of composition of the tachylite and ordinary variety of a dyke obtained by Judd and Cole from a study of the dykes of the Western Isles of Scotland, which we will now briefly refer to.

We know of but one more example of a glassy rock of this kind from the North of England dykes,[1] so that it will be interesting to compare the Teesdale tachylite with that from the Western Isles of Scotland. The dykes differ fundamentally in the presence of olivine in the Scottish rocks and its absence from the Cleveland Dyke—at all events, at this exposure the latter is an augite-andesite, while the former are described as olivine basalts; the non-magnetic character of the Teesdale tachylite also distinguishes it, and it seems probable that the oxide of iron exists in a different form in this rock, as ferric oxide, or at least not combined to form magnetite as seems to be the case in the Scottish variety. The latter is also an exception to the rule that the specific gravity of the tachylite is less than that of the ordinary variety of a dyke; we have already seen that the tachylite of the Cleveland Dyke conforms to this rule. It is interesting to note that both the glassy rocks contain corroded augites and felspars, showing that the conditions of intrusion of the two magmas must have been similar. In chemical composition there is a great resemblance between the two rocks.

When examined under the microscope the slides show a glassy rock passing abruptly into a larger mass of true tachylite about $\frac{1}{3}$ inch in thickness at the outer margin; the sections fall naturally into the following divisions (see Pl. IV, Figs. 1, 2):—

I. Tachylite
- (*a*) Pale pinkish-brown layer.
- (*b*) Bright yellow layer in contact with (*a*).

II. Stony rock
- (*a*) Dark granular region of irregular limits merging into
- (*b*) Light-grey area in which swirling black streams still mark the 'lines of flow'.

Flow-structure, indeed, is evident in both the main divisions of the section: in the tachylite the lines run parallel to the junction; in the stony layers beneath they curve and twist about much more, at a little distance below the actual contact, but with a general trend in its direction.

THE TACHYLITE (Plate IV).—The spherulitic nature of the tachylite is quite plain in ordinary light, for the presence of chlorite in the interstices serves greatly to emphasize the outlines of the spherules. The yellow band, Fig. 1 (Ib) differs in no important point from the upper tachylite,

[1] A slide of this rock in the collection of Dr. Teall was examined, with his kind permission, by Miss Heslop; it is marked "Tachylite, $3\frac{1}{2}$ miles east of Greenhaugh", and contains well-formed porphyritic augites (with large optic angle) not unlike those of the Cleveland Dyke, but they are pierced by ground-mass felspars.

and its colour—the only distinction—is certainly the result of contact with the highly ferruginous dark rock below it. A somewhat different character was shown by a fresher specimen of the chilled margin (Pl. IV, Fig. 2) from which a section was cut, more or less parallel to the contact surface of tachylite and 'stony rock'. The fresh glass in this instance was brown, isotropic, and apparently quite amorphous (BG, Fig. 2), for, though it was suggestively granular, no actual grains could be focussed. Light-yellowish bands (C, C) of varying thickness (0·08–0·09 mm.) cross the dark glass in all directions, dividing it up into somewhat angular areas, which show faint but distinct zones of colour (Z, Fig. 2), pale on the outside but grading down to the normal dark brown at the centre of each patch. The light-yellow bands (C, C) consist of distinct fibres (ch, Fig. 2), which lie at right angles to a central crack. In every case a crack seems to have been the starting-point for the devitrification process. There can be little doubt that the cracks themselves are due to cooling.

Lines of flow such as are seen in the layers beneath the tachylite or even in transverse sections of the tachylite itself do not occur here, but certain proof of flow-movement is available in the drawn out and distorted bubbles, which are quite common (see b, b, Fig. 2). Some of them are black and opaque and seem to have an internal cavity, but there are others (X) which present rather the appearance of a highly refracting material of golden brown colour, not unlike rutile. They are brilliantly polarizing, but clearly owe their interference colours to small pleochroic laths felted together, which must either form the walls or be the decomposition product of some substance now filling the gas cavities. There can be no doubt, from their parallelism and general likeness, that the black-lined cavities and the yellow highly polarizing areas are of similar origin, but that a deposit of iron-oxide has produced the dark colour in one case, while devitrification is responsible for the pleochroism and double refraction in the other. The local concentration of iron-oxide here finds a parallel in the lower layers, where alternating dark and light 'streams' indicate the local abundance and scarcity of granular iron-oxide.

Porphyritic felspars and augites, besides small varieties of both these minerals, occur plentifully in the tachylite. All the crystals are faulted by the cooling cracks when they lie in their paths, and, more than once, small augites were seen apparently dividing the distorted bubbles, thus showing that they were formed prior to the movement which drew out the bubbles into their present elongated shape. There is a perfectly sharp line of division between the tachylite and the adjacent rock, and although practically the same crystals exist on both sides of this line, the bases in which they are embedded are quite distinct.

The Stony Rock.—This consists mainly of masses of yellowish-green fibres, among which lie small specks of iron-oxide; these accumulate in greater numbers and attain a much greater size in the dark area and in the dark bands, whose meanderings indicate the flow-lines at this part. It is to the iron-oxide specks that the granular appearance of the 'stony rock' is due, and an increase in their size and number is apparently accountable for the darker regions of the base here.

In the less disturbed places, where flow-structure is not greatly in evidence, the fibres sometimes attain the size of ordinary skeleton augites, which they resemble in general mode of occurrence. Individual needles sink to the minutest dimensions, however, in the disturbed parts and lose their parallel disposition, becoming more felted together without definite plan or arrangement. These differences may be taken as indications of the stages of incipient crystallization produced under the two circumstances; in neither is it far advanced, but those parts which solidified with moderate quiescence allowed more opportunity for the development of the skeleton growths, whose decomposed form, supplemented by further devitrification, we now see in the parallel bundles of green needles. There is therefore no structural affinity between the base of the tachylite and that of the adjacent 'stony rock'.

Crystals are sparsely but uniformly distributed throughout the slides, and are as abundant in the tachylite as in the 'stony rock'. The *porphyritic felspars* seem to belong chiefly to the andesine variety, but they approach labradorite in the central parts of the crystals and pass into a more alkaline type in the outermost zones. Many of the smaller laths must also be classed with andesine, and while some are undoubtedly labradorite there is, on the other hand, a transition towards oligoclase. On the whole, however, there is little range of composition; the majority belong to andesine, and exceptions in either direction are rare. Those porphyritic crystals and groups which are found in the tachylite are not much altered, but some of the porphyritic individuals of the 'stony rock' are often greatly decomposed, faulted by cooling cracks, and crushed, while others seem to have been overwhelmed by the 'lines of flow'. The smaller laths, binary twins for the most part, are quite frequently bent or even broken, especially in the tachylite.

The *large augites* have suffered more severely from magmatic corrosion than the felspars. Some crystals are curved, some are invaded by masses of glassy base, while all alike are characterized by rounded angles. They seem to be typically rather broad octagonal prisms of pale yellowish-brown colour, and are distinctly pleochroic. The largest crystals were too much deformed to permit of a thorough optical examination, but two smaller ones showed practically uniaxial interference figures, which is in agreement with the character of the older augites of the Cleveland Dyke.

Small augites are by far the most abundant crystalline constituent of the rock at this part. They occur in small beautifully sharp-edged octagonal prisms, which are generally grouped together but rarely intergrown. They are not noticeably pleochroic. There is none of that bleaching of the groundmass in their neighbourhood, which is frequently found in the vicinity of small ferro-magnesian minerals embedded in a dark glassy matrix. The extinction angle on the B(010) face is from 35° to 40°.

There are small groups of felspar often stellate in arrangement, bound together by a central cluster of granular augite (Plate IV, AF in Figs. 1 and 2). An apparent development of this on a larger scale shows a central patch consisting entirely of granular augite—often resembling a spherulite in the radial arrangement of its small crystals—which is outlined as a rule by tangentially disposed felspar laths. There are several such patches both in the tachylite and in the 'stony rock', but they are more numerous in the latter. In all cases, however, the patches in this contact variety of the Cleveland Dyke are much smaller, both in general outline and in the internal development of their crystalline constituents, than similar structures occurring in the interior of the intrusion (e.g. in the centre of the Bolam laccolite), so that the suggestion which has more than once been put forward to account for them—that they are a lateral fine-grained variety of the typical rock, which has been broken up and floated away by later re-heating—receives a distinct check (though not actual disproof) by their scarcity at the margins and their abundance and large development in the central portions of the intrusion. Moreover—and it has been observed and mentioned elsewhere [1]—these groups are absolutely holocrystalline (which is unusual in marginal solidifications), and they always consist of an internal granular mass of augite with a few grains of iron-oxide and an external border of felspar laths.

This paper deals principally with the contact variety, but it would be incomplete without some reference to the typical rock. The general structure and mineralogical composition of the Cleveland Dyke are too well known to need more than the briefest description here. The dyke is classed by Dr. Teall in his *British Petrography* as an augite-andesite, "porphyritic in texture, the porphyritic character being determined by the presence of tabular crystals of labradorite . . . still recognizable at chilled margins." In the specimens of the typical rock which were examined the felspars were indeed similar to those in the tachylite, but were much more numerous. The majority, however, including the porphyritic individuals, must still be referred to andesine rather than to labradorite, though examples of the latter variety do occur. There is a greater range towards the alkaline end of the felspar series here than in the tachylite. Several felspars with the mean refractive index of oligoclase were seen, and some sank to that of albite. These were large well-formed crystals, but, in the case of the albite, of somewhat ill-defined outlines. The typical augites of the Cleveland Dyke will, it is hoped, be fully described in a subsequent paper; it is sufficient at present to say that they are identical with those of the tachylite. Iron-oxide occurs in no great abundance, and even in the central parts of the intrusion it exists in small incomplete or skeleton forms, so that its granular nature at the margin is in no way remarkable.

The marginal type of groundmass is described by Dr. Teall as

[1] "On the Crookdene and Related Dykes," by Miss M. K. Heslop, M.Sc., and Dr. J. A. Smythe, Q.J.G.S., February, 1910. The suggested explanation of the micro-crystalline groups given in this paper has received support from subsequent observations, and especially from the case under discussion. Dr. Teall very kindly lent me some slides of the North of England dykes, and one was found to satisfy almost perfectly the requirements of a semi-vitreous marginal solidification, which had been broken up into more or less angular fragments by a later re-heating. In this case the fragments consisted of devitrified glass, in which were embedded various elementary crystals, while they (the fragments) were embedded in a similar devitrified glass with some quartz.—M. K. H.

a "veritable mikrolithen filz, a closely-matted aggregate of minute felspar microliths", and this is, in general, the character at the borders of the Bolam and Cockfield laccolites; it is in strong contrast to the almost homogeneous glass with its small supply of felspars, which is discussed in this paper. It is true that a little earlier in the same paragraph as the above quotation we find that "in one instance only was an isotropic glass observed, and then the glass was seen to contain longulites and globulites similar to those in the Eskdale Dyke". This cannot be said of the Teesdale tachylite, for although it contains crystals they have, even the smallest (which are seen penetrating bubbles) been formed before they reached their present position, where there is no evidence of crystallization having proceeded; for the glass, where undevitrified, is absolutely homogeneous, so far as can be determined by present microscopic appliances.

It will be convenient here to discuss a few points concerning the petrology, and the relations between the tachylite and the glass of the groundmass of the dyke. Some very interesting conclusions may be drawn from the observations on the connexion between the cooling cracks and the crystals of the tachylite. It has been pointed out that two generations of crystals occur—

1. The porphyritic felspars and augites.
2. The groundmass felspars and augites, few and small, and it has been shown that all these crystals were formed prior to the tachylite itself, which was undoubtedly produced in situ by rapid cooling at the edge of the dyke. The history of the magma is, therefore, as follows.

The porphyritic crystals were formed first, and were floated up by the magma from a fairly low depth, when it was intruded into the fissure; but on the way cooling began, possibly during periods of quiescence, and new crystals of a later generation were formed, and probably the zoning of the felspars commenced. The residual magma was rapidly cooled where it came into contact with the walls of the fissure, and the tachylite was formed; this glass, then, we may term the 'primary groundmass', enveloping crystals of two generations, the later generation being one of extended duration. But in the centre of the dyke crystallization proceeded, yielding the groundmass crystals and continuing the zoning of the felspars; finally, we had left the 'later groundmass', which according to Stock's analysis is of acidic composition. One glass is thus, in a way, formed from the other, and the groundmass of the dyke is a product of differentiation by crystallization from a material having the same composition as the tachylite, which is an intermediate rock. Moreover, the glass of the groundmass analysed by Stock is much richer in alkalies than the tachylite or the ordinary variety of the dyke, so that it is not surprising to find that the outer zones of the porphyritic felspars are of a more alkaline type than the inner zones; and even whole crystals of albite occur. Thus, as differentiation by crystallization proceeded we had felspar material of a more alkaline type crystallizing out, and it is evident that the albite crystals were the last formed; and from their ill-defined outlines it is inferred that they had not time to fully develop.

This supplies us with a good example of the power of differentiation by crystallization, and it seems probable that if pressure had supervened, so as to strain off the crystals of the 'later groundmass' and squeeze out the latter, an acidic rock would have resulted. Although this possibility was not realized in this case it has been an important factor controlling differentiation in other instances.

General Review and Conclusions.

We find a 'stony rock', consisting of a base in which there is evidence of incipient crystallization, passing quite abruptly into a layer of tachylite ($\frac{1}{4}$ to $\frac{1}{3}$ inch) in thickness. The 'stony rock' is granular in appearance owing to the presence of minute specks of iron-oxide. These increase markedly in size and number in the rock adjacent to the tachylite, giving rise to the 'dark area'. Dark streaks of a similar nature mark the lines of flow in the paler rock (Pl. IV, Fig. 1).

The spherulitic devitrification of the tachylite in contact with the adjacent layers may be evidence of a not perfectly homogeneous condition at the time of solidification, but the outer part of the glass is certainly homogeneous, for there the devitrification is clearly guided by the cooling cracks along which it started.

There are crystals—porphyritic and smaller individuals—in both parts of the slides, but they are much more altered, faulted, and deformed in the 'stony rock'. Some curved felspar laths in the tachylite show that the temperature there had approached that of their melting-point. Small masses of granular augite associated with felspar laths, either in stellate groups or tangentially disposed to form a border, occur here as well as in other parts of the intrusion. They have been found in every section from all localities, but they are certainly largest and most numerous in the central parts of the dyke. That they are smaller and rarer here is distinctly opposed to the idea that they are a fine-grained lateral consolidation, which has been broken up by a later melting of the rock, while there is nothing to disprove the suggestion of a local eutectic mixture produced by the progressive abstraction of material in a small area walled off by the crystals (felspars usually), which by withdrawing materials for their own growth give rise, instantaneously perhaps, to the conditions necessary for the spontaneous crystallization of the remainder.

The distribution of the cracks is interesting. In the outer part of the tachylite they are ubiquitous; then they become scarce and never extend into the adjacent 'stony rock'. In this latter one set of cracks runs at right-angles to the junction, but no crack passes into the tachylite. Another set, more or less parallel to the junction of the two types of rock, bounds the very irregular limits of the 'dark' rock, while a third set converges towards the second at a large angle and does not as a rule pass it.

The dark area seems to bear the same relation to the adjacent rock that the tachylite bears to it; in other words, it would seem that the tachylite cooled first, forming a rather firm viscous film, past which the still molten magma continued to flow. Evidence of this is found in the appearance of one or two large felspars, which suggest having been rammed up against the tachylite layer and even forced a little way into it, breaking during the process. Evidence, too, of the viscosity of the tachylite is found in one of its felspar laths which curve with the curve of the junction line between the tachylite and stony rock.

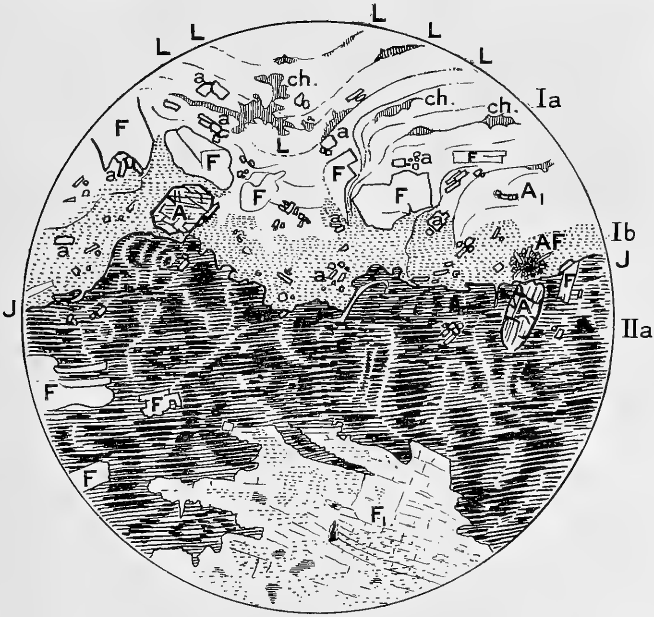
The dark area probably cooled next and adhered to the firm surface of the tachylite, while movement, either of flow or more probably of contraction and contortion due to cooling and settling down of the great mass of the dyke, continued in the adjacent regions. For this reason portions of the dark layer are torn down and tongues of paler rock are forced right up to the tachylite. There can be little doubt that the rapid formation of the film of tachylite retarded the cooling of the adjacent magma, and thus the marked difference between the glass and stony rock is accounted for, while their perfect contact is due to the adherence of the continually cooling material to the only firm surface in the vicinity, that of the tachylite, contact with which further accelerated cooling. There would thus be a continually increasing number of layers of viscous rock bound together more closely than to the adjacent mobile material. Comparison with a typical section of the Cleveland Dyke (from Cockfield) shows that the porphyritic felspars have the same appearance and composition, but while most of the smaller laths belong to andesine with a little labradorite there is a noticeable development of more alkaline species in the Cockfield specimen but not in the tachylite. This is readily understood: the alkaline felspars are among the later crystallizations, which were entirely checked in the tachylite. The large augites are the same in both cases. The small augites of the typical rock are about twice or three times as large as the corresponding crystals in the tachylite, and while the former often have a surface coating of black grains of iron-oxide, the latter are absolutely free from them. Iron-oxide, indeed, does not occur as a primary crystalline constituent in the tachylite. Comparison with other contacts, as well as with the typical rock, shows that a marked suppression of the smaller felspars must have taken place in the tachylite, while an impetus was apparently given to the formation of small augites. This indicates a local inversion of the usual order of crystallization, which generally places felspar before augite in each generation in the Cleveland and many other dykes.

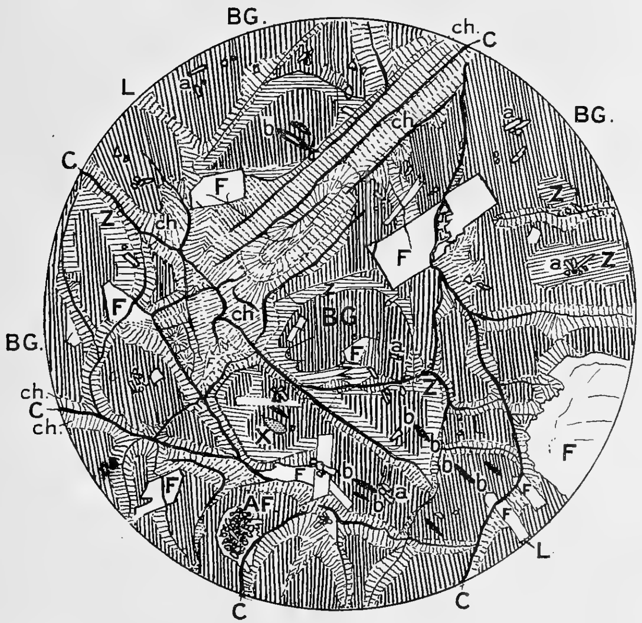
EXPLANATION OF PLATE IV.

FIG. 1. Junction of Tachylite and 'Stony Rock', Cleveland Dyke.

Ia. Tachylite, pinkish-brown layer.
Ib. Bright-yellow (stained) band in tachylite.
IIa. Dark layer of stony rock.
L, L. Lines of flow, only shown here in tachylite, but very clear in the stony rock.
F. Felspars. F_1, large, deformed, and partly decomposed individual.
A. Large augites. A_1 is a small prism, faulted and drawn up by a 'flow' line.
a. Small augites usually in groups.
ch. Areas occupied by green chlorite. Their shape is determined by the spherulites (only seen with crossed nicols) in the tachylite.
AF is a group of felspars with a central cluster of granular augite.

FIG. 1.





M. K. Heslop del.

FIG. 2.

Tachylite, Cleveland Dyke.

J, J. The line of junction between tachylite and stony rock is perfectly sharp. It is seen apparently truncating a small felspar on the right-hand side, while a curved lath is seen just below the contact near the centre of the figure. The cracks in the lower layers are not well shown.

FIG. 2. Shows a section cut roughly perpendicular to the upper part of Fig. 1.

C, C. Cooling cracks. ch. The chlorite fibres bordering them. BG. Dark-brown isotropic glass. Z. Zones of paler glass. F. Felspars often faulted by cooling cracks. The direction of flow (L, L) is shown by the shape and parallelism of the black cigar-shaped bubbles (b, b); some of these are apparently hollow, while a yellow variety is shown at X. It is quite evident that the cooling cracks here (C, C) have no connexion with the direction of flow; indeed, they are sometimes seen faulting the bubbles.

IV.—The Late Palæozoic Alkaline Igneous Rocks of the West of Scotland.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Assistant to the Professor of Geology, Glasgow University.

Introduction.

Of late years it has become manifest that the igneous rocks of the Carboniferous in Central Scotland have a distinct alkaline facies. Such rocks as monchiquite, nepheline-basalt, mugearite, kulaite, phonolite, essexite, and teschenite have been described from the Lothians; whilst in the western counties nepheline-phonolite, theralite, mugearite, and teschenite are already known. There is abundant evidence, however, that in the West the alkaline phase is of later date than in the Lothians, and of late Carboniferous or Permian age. In Arran it probably extended into the Triassic, assuming that the stratigraphy which assigns certain rocks to the Triassic is correct. A general account of this connected suite of alkaline rocks, together with the lavas in the Mauchline Basin, to which they can be shown to be genetically related, is given in this paper, which deals only with rocks demonstrably later than the volcanics of the Calciferous Sandstone. The work on which this paper is based was commenced in 1908, and was assisted in 1909 by a grant from the Government Grant Committee of the Royal Society, for which grateful acknowledgment is made. An unfortunate breakdown in health, however, necessitated the postponement of the investigation for nearly a year. It is still incomplete owing to the difficulty of obtaining adequate chemical analyses, without which it is impossible accurately to determine the affinities of some of the rocks. Pending the completion of the detailed work it has been thought advisable to present this preliminary account of an igneous suite of extraordinary variety and interest.

Literature.

A brief account of the literature has been given in an earlier paper.[1] Allport described some of the rocks in his classic paper on "The Carboniferous Dolerites".[2] Teall first recognized the teschenitic

[1] Trans. Glasgow Geol. Soc., vol. xiii, pt. iii, p. 300, 1909.
[2] Q.J.G.S., vol. xxx, pp. 529–67, 1874.

affinities of the intrusion of Necropolis Hill, Glasgow.[1] Many details of geological occurrence and petrography are to be found in Sir A. Geikie's *Ancient Volcanoes of Great Britain.*[2] Numerous notes have been contributed by the Geological Survey during recent years. Analyses of the Barshaw theralite and the Lennoxtown essexite have been made; [3] whilst the occurrence of nepheline in some of these rocks was recorded by Bailey in 1909.[4] The teschenites of the vicinity of Glasgow have been described by Macnair,[5] and the teschenite-picrite sill of Lugar by Boyle.[6] A classification of the Post-Carboniferous igneous intrusive rocks of the West of Scotland was given by the writer in 1909, but that classification must now be amended and supplemented in many particulars.[7]

Petrography.

A brief systematic description of the main types of intrusive rocks and of the Mauchline lavas is here given. Much mineralogical detail of great interest and importance and also the detail of field geology is necessarily omitted or greatly curtailed, but will be given at length in the detailed papers which it is hoped will soon be published.

The intrusive rocks may be classified broadly into three groups—

A. Rocks with conspicuous analcite.
B. Rocks with conspicuous nepheline.
C. Rocks without conspicuous analcite or nepheline, but which may contain either or both as accessory constituents.

A. *Rocks with conspicuous Analcite.*

These may be subdivided into five groups as follows:—

1. Analcite-syenite, in which an alkali-felspar is predominant.
2. Teschenite, in which a lime-soda felspar is predominant.
3. Picrite-teschenite, an ultra-basic differentiation facies of teschenite.
4. Lugarite, a leucocratic rock with affinities to ijolite.
5. Monchiquite, a lamprophyric sub-group.

Of these the teschenites are by far the most abundant.

1. *Analcite-syenite.*[8]—This exceedingly rare rock-type is found in a remarkably fresh and perfect occurrence at Howford Bridge, near Mauchline, Ayrshire. It is exposed in the cliffs of the River Ayr, and forms a lenticular intrusion into the lavas and tuffs which underlie the 'Permian' red sandstones of the district. In hand-specimens the rock is medium to fine grained and whitish in colour. It consists mainly of well-shaped felspars with a general parallel arrangement giving a trachytoid aspect to the rock. The long acute-angled interspaces are filled with greenish analcite and dark ferromagnesian minerals. The most prominent constituents,

[1] *British Petrography*, 1888, p. 194.
[2] Vol. ii, pp. 58–67, 1897.
[3] *Summary of Progress of Geological Survey for 1907*, 1908, p. 55.
[4] Ibid. for 1908, 1909, p. 44.
[5] Trans. Glasgow Geol. Soc., vol. xiii, pt. i, pp. 56–86, 1907.
[6] Ibid., vol. xiii, pt. ii, pp. 202–23, 1908.
[7] Ibid., vol. xiii, pt. iii, pp. 298–317, 1909.
[8] *Nature*, vol. lxxxii, p. 188, 1909.

however, are large black, lustrous crystals, the lustre of which is interrupted by metallic patches which themselves become lustrous when the rock is held in a different position to the light. These lustre-mottled aggregates are composed of titanaugite[1] and ilmenite, and occur in increasing abundance towards the base of the sill. In an acid variety of the rock which occurs in contemporaneous stratiform bands and veins ranging up to 2 feet in thickness these augite-ilmenite aggregates are absent.

In thin section the rock is found to be composed principally of alkaline felspars (anorthoclase, orthoclase, albite) and very subordinate labradorite, with abundant interstitial analcite of perfect freshness and limpidity. The felspars and analcite make up the great mass of the rock. The ferro-magnesian constituents include titanaugite, ægirine, brown and blue soda-amphiboles, ilmenite, and occasionally a very little olivine. The texture is medium-grained, and the fabric equigranular to trachytoid.

In the analcite-syenite proper anorthoclase is the dominant felspar. It occurs in well-shaped square or rhomboid sections frequently showing the minute microcline twinning characteristic of this mineral. It is usually bordered by a broad zone of orthoclase. Albite occurs as occasional perthitic intergrowths, as independent idiomorphic crystals, and as a product of the 'albitization' of the labradorite. It is nevertheless not abundant. In the more basic types labradorite forms broad zonally-built crystals ranging in composition from $Ab_1 An_1$ to $Ab_3 An_1$.

These felspars are loosely aggregated together and appear as if floating in the abundant analcite which fills all the interspaces. The latter is fresh and limpid, and shows beautiful cross-hatching similar to that of leucite. Numerous idiomorphic crystals of ægirine and of brown and blue soda-amphibole (barkevicite and arfvedsonite) are enclosed in the analcite. These are frequently found in confused, tangled crystal aggregates at one side, or in one of the angular bays, of an analcite area. There can be but little doubt that these crystals gravitated into the lower portion of the analcite area as the latter was situated during the cooling of the magma. This fact, together with the perfect idiomorphism of most of the constituents of the rock, affords impressive testimony, not only of the long duration and high degree of liquidity of the residual magma, but also of the primary nature of the analcite.

In the more basic varieties of the rock titanaugite is a prominent constituent. It is of a variable purplish-brown tint, becoming green on the margins where it adjoins an alkali felspar or an area of analcite. It is frequently shot through with large skeletal crystals of ilmenite in blebs, patches, and strings extending right through and beyond the boundaries of the crystals. These form the large lustre-mottled aggregates prominent in some hand-specimens. Apatite occurs abundantly in small bifid crystals usually enclosed in the analcite.

[1] This term is used throughout for augite with the purple-madder tint supposed to indicate a high titanium and alkali content.

The mineral composition of the two principal varieties, estimated by the Rosiwal method, is given in Table I.

TABLE I.

	I.	II.
Analcite	8·1	15·9
Alkali-felspar	54·7	66·8
Labradorite	5·2	—
Titanaugite	15·1	—
Ægirine	3·3	9·3
Soda-amphibole . . .	1·6	4·3
Titano-magnetite . . .	7·9	2·5
Olivine	2·6	—
Apatite	1·5	1·2

I. Main mass of intrusion.
II. Acid bands and veins.

Chemical composition. The normal analcite-syenite of Howford Bridge has been analysed by Dr. Dittrich of Heidelberg with the result set forth in column I of the Table below. With it are tabulated for comparison the analyses of three other rocks.

TABLE II.

	I.	II.	III.	IV.
SiO_2 . . .	56·44	55·95	58·46	60·15
TiO_2 . . .	1·16	·45	·28	—
Al_2O_3 . .	15·54	18·60	16·56	18·04
Fe_2O_3 . .	3·27	2·60	5·69	4·44
FeO . . .	3·67	5·22	2·59	1·82
MnO . . .	—	—	—	·13
MgO . . .	1·73	3·17	·62	·98
CaO . . .	4·16	3·97	2·62	1·68
Na_2O . . .	5·81	5·15	6·23	6·07
K_2O . . .	4·27	4·00	5·44	4·15
H_2O + . .	2·06	} ·50	1·21	
H_2O − . .	·44			} 2·06
CO_2 . . .	·97	—	·04	
P_2O_5 . . .	·83	—	·23	—
Cl . . .	—	—	·29	—
	100·35	99·61	100·26	99·52

I. Analcite-syenite, Howford Bridge, Mauchline, Ayrshire.
II. Ditroite, Ampangarinana, Madagascar: Lacroix, Nouv. Arch. du Mus. (iv), vol. iv, p. 19, 1902.
III. Pulaskite, Cabo Frio, Rio de Janeiro. Quoted in Rosenbusch, *Elem. der Gest.*, 3rd ed., 1910, p. 128.
IV. Phonolitic trachyte, North Berwick Law, East Lothian. Quoted in *Geology of East Lothian*, Mem. Geol. Surv., 1910, p. 130.

The analysis shows that this analcite-syenite belongs to the group of the alkali-syenites, and not to the felspathoidal group. The Madagascan ditroite quoted does not contain nearly so much alkalies as the usual run of nepheline-syenites, and seems rather to belong to the alkali-syenites. The comparatively high lime content in the Howford Bridge rock, due to the abundance of pyroxenes, is to be noted, as it is a point of difference with the majority of the alkali-syenites. This feature links the rock to the umptekites, but no very concordant analysis of the latter could be discovered. Amongst previously described Scottish Carboniferous rocks, the phonolitic trachytes of East Lothian, notably that of Berwick Law, show decided chemical affinities with the Howford Bridge rock, as may be seen by comparing Analysis IV with I. These rocks are said to contain analcite and probably pseudomorphs after nepheline.[1]

Towards the base of the Howford Bridge sill the proportions of titanaugite, iron-ore, and labradorite increase rapidly, and the rock passes into an essexite-dolerite identical with those described later (in Part II). The contact facies is a dense splintery basalt of similar composition. A thin layer of essexite-dolerite also forms the upper contact of the sill, but it passes rapidly downwards into the normal analcite-syenite. The sheath of essexite-dolerite surrounding the analcite-syenite is penetrated by numerous irregular anastomosing veins of the latter rock. It is probable that in this sill we have a case of gravity differentiation similar to that of the Lugar (pp. 75, 76) and Benbeoch (*infra*) masses.

Another occurrence of analcite-syenite is known from a sill intruding the 'Permian' lavas in the Dippol Burn, 1½ miles north of Ochiltree. Here, however, the analcite-syenite occurs in thin contemporaneous stratiform bands in an essexite-dolerite which forms the major part of the sill. The rock is generally similar to that described above, but the rhomboid form of the felspars and the trachytoid structure is accentuated. Veins of analcite-syenite occur also in the essexite-dolerite of the Trabboch Burn, near Stair (see Part II of paper).

Analcite-syenite of a different type is to be found in the numerous aplitic veins which penetrate many of the teschenites. These are fine-grained light-coloured rocks forming veins up to 2 inches in width. In the Necropolis (Glasgow) teschenite the veins are composed of a plexus of plates and idiomorphic prisms of orthoclase, sometimes moiré and perthitic, embedded in an abundant groundmass of dusty analcite. A little analcitized labradorite may also be present. Some flakes of a bleached biotite and a few skeletal crystals of ilmenite are the only ferromagnesian minerals to be found. In one slide, however, there are a few needles of ægirine, and some sections, the shape and mode of decomposition of which suggest the presence of nepheline. The texture is fine and even-grained, and the rock might be termed analcite-syenite-aplite. Veins occur in many other teschenites, notably the Galston type, in which they are quite coarse-grained hypidiomorphic syenites.

2. *Teschenite.*—Rocks belonging to this group are very abundant, and are fairly uniform in character. The sill of the Necropolis Hill,

[1] Mem. Geol. Surv., *Geology of East Lothian*, 1910, p. 130.

Glasgow, is a typical example. This rock has been often described, first by Teall,[1] later by Macnair,[2] and finally a complete account has recently been given by Bailey.[3] Hence it is unnecessary to describe the rock in this place. It seems appropriate to designate this common and widespread variety of teschenite as the *Glasgow type* since it was first described by Teall from the Glasgow occurrences. The mineral composition of the Lugar teschenite, given in column II, Table III, may serve as the quantitative definition of the Glasgow type, as it is practically identical with the Necropolis Hill rock.

The contact facies is a black basaltic rock consisting microscopically of a fine-grained holocrystalline aggregate of plagioclase, augite, olivine, and analcite, frequently with abundant biotite and red hornblende. The ferro-magnesian minerals, especially olivine and biotite, are distinctly more abundant than in the coarse central facies, and the rock takes on a lamprophyric habit. If occurring as an independent mass it would doubtless be assigned to the camptonite group.

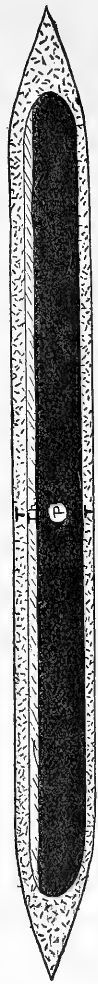
Rocks of the Glasgow type are abundant in the east of Glasgow, and also at Shettleston, still farther east. In Ayrshire they occur near Old Cumnock, Skares, Lugar, Galston, Stewarton, Ardrossan, and Troon. In Arran perfectly similar rocks are found intruding the Triassic at Dippin Head.[4] Numerous occurrences of teschenite from the Lothians have been described and some analysed.[5]

A sub-variety of the Glasgow type occurs at Galston, Shettleston, and elsewhere. It is characterized by the abundance of large pseudo-porphyritic augite crystals and has a distinctive appearance in hand-specimens. The large augites are set in a fine-grained groundmass of plagioclase, orthoclase, and analcite, which is practically free from ferroclase-magnesian minerals. A little biotite, olivine, and ilmenite may be present. This rock may be referred to as the *Galston type*.

A quite distinct variety of teschenite occurs in a group of sills at Cathcart, near Glasgow. It is a fine-grained nepheline-bearing rock which may be regarded as intermediate between the true teschenites and the theralites of the Barshaw type (p. 80). It consists of plagioclase, titanaugite, olivine, red hornblende, analcite, nepheline, and ilmenite. Olivine is in greater and analcite in less quantity than in the Glasgow type. Nepheline is fairly abundant in broad plates which envelop felspars and flakes of biotite. In addition this rock differs from the Glasgow type in the habit of the augite, which occurs mostly in polysomatic groups of small subhedral grains. This, together with the finer grain and the greater abundance of the femic constituents, gives it quite a different aspect in thin section to that of the Glasgow type. It may therefore be called the *Cathcart type*. Similar rocks occur at the Linn Falls on the River Cart, near Cathcart, the Glengyron railway cutting near Old Cumnock, and in

[1] *Brit. Petrog.*, 1888, p. 194; see also pl. xiii.
[2] Trans. Glasgow Geol. Soc., vol. xiii, pt. i, pp. 79–82, 1907.
[3] Mem. Geol. Surv., *The Geology of the Glasgow District*, 1911, pp. 114–16, 132–3.
[4] Harker, Mem. Geol. Surv., *Geology of North Arran, etc.*, 1903, p. 112.
[5] Mem. Geol. Surv., *Geology of East Lothian*, 1910, p. 114, and *Geology of the Neighbourhood of Edinburgh*, 1910, pp. 293–301.

the contact facies of the Ardrossan picrite-teschenite sill. Mr. Bailey has described the rock as nepheline-teschenite, and regards it as allied to the porphyritic essexite of Lennoxtown.[1] Some of the teschenites show leucocratic and melanocratic modifications. This is well seen in the extraordinary complex of the Lugar teschenite-picrite (p. 77). The leucocratic variety is a coarse-grained pinkish rock rich in analcite and orthoclase, whereas in the melanocratic variety the felspar and analcite total only about 20 per cent of the mass. In texture this rock resembles the Cathcart rather than the Glasgow type.



Diagrammatic longitudinal section of the picrite-teschenite sill, Lugar. T=Teschenite; Th=Theralite; P=Picrite. Not drawn to scale. Length of sill $3\frac{1}{2}$ miles, thickness 140 feet.

3. *Picrite-teschenite.*—In two or three cases the differentiation of a basic teschenite has given rise to a considerable body of ultra-basic rock. The most remarkable instance of this occurs at Lugar in Central Ayrshire.[2] This intrusion, which is magnificently dissected by the Bellow and Glenmuir Waters, contains an extraordinary assemblage of analcite and nepheline-bearing rocks. It is a sill about 140 feet in thickness, and intrudes a white sandstone belonging to the Millstone Grit. At both upper and lower contacts is a black basaltic rock grading insensibly, through fine-grained varieties, into a typical coarse teschenite of the Glasgow type. Below the upper teschenite comes about 10 feet of beautifully fresh theralite with abundant nepheline. This rock, of which there are two varieties, differs from the Barshaw rock (p. 80) in several particulars, and will be described under the head of theralite. It rests upon a great thickness of picrite or peridotite, which, in its turn, rests upon the lower teschenite, but without the intervention of a theralite zone. The ultra-basic rock occupies about five-eighths of the total thickness of the sill (see Figure).

In hand-specimens the picrite is medium- to coarse-grained, blackish-green in colour, and frequently exhibits flashing, lustre-mottled plates of hornblende. Microscopically it is composed of olivine in more or less rounded grains, ranging up to half an inch in diameter, and in all stages of alteration to blue, green, yellow, and colourless serpentine. It is often quite fresh and forms about 65 per cent of the rock. The next most abundant constituent is titanaugite, which totals about 21 per cent. It occurs as numerous, minute, euhedral grains in little clusters or polysomatic groups wedged in between the olivines, and where the latter is altered, enveloped in serpentine. Hornblende occurs to the extent of 10 per cent in large irregular plates

[1] *Summary of Progress of Geological Survey for 1908*, 1909, p. 45; also Mem. Geol. Surv., *Geology of the Glasgow District*, 1911, p. 131.
[2] Boyle, Trans. Glasgow Geol. Soc., vol. xiii, pt. ii, pp. 202–23, 1903.

poikilitically enclosing both olivine and augite. It is a red-brown variety belonging to barkevicite. A very little ilmenite (3 per cent) is enclosed in the hornblende, but the rock is remarkable for the scarcity of iron-ore. A few flakes of red biotite, of later crystallization than the augite, are seen occasionally. There is no apatite, as that mineral always seems to go with abundant analcite. This rock differs from the Inchcolm type[1] in the absence of felspar, the abundance of hornblende, and the granular habit of the augite. It may be referred to as the *Lugar type*. The rock is so rich in olivine that it should perhaps be called a peridotite. Towards the top of the ultra-basic mass, however, the proportion of olivine lessens, and a considerable quantity of plagioclase and analcite comes in. The percentage mineral composition of this rock is shown in column VII of Table III (p. 77). There is also a variety in which the augite totals over 50 per cent of the mass (column VI, Table III). These rocks are true picrites, comparatively rich in the bisilicate constituents, and containing some felspar.

It is not intended here to discuss the cause of the remarkable differentiation which has given rise to the varied assemblage of rock-types within the Lugar complex. Briefly the writer believes that it is due to a stratification of the magma under the influence of gravity—a separation of heavier from the lighter and more volatile constituents—which began before crystallization commenced and continued for some time after. This stratification took place within a shell of viscous or solid material slowly growing out from both contacts, and was rendered possible by the abundance of a water-rich mother-liquor which subsequently crystallized as analcite. The presence of this mother-liquor is believed to have maintained the magma in a state of great liquidity for a long period of time, and thus facilitated differentiation under the influence of gravity. Numerous facts and observations, for the full statement of which a later detailed paper must be consulted, give support to this hypothesis.

Table III shows the percentage mineral composition of the rock-types appearing in the complex, arranged as a series from the top to the bottom of the sill. These have been obtained by the Rosiwal method, to which these fresh, medium-grained rocks lend themselves admirably.

A picrite-teschenite sill, very similar to that at Lugar, occurs on the Ayrshire coast at Castle Craigs, Ardrossan. It has been described by Falconer,[2] who, whilst noting the abundance of analcite, has identified the rocks as hornblende-dolerite and picrite. Close to the upper contact the rock is a nepheline-teschenite of the Cathcart type, containing abundant red hornblende, which is indeed a characteristic mineral of the whole suite. Nepheline is also fairly abundant. This rock passes downwards into a teschenite of the Glasgow type, but with more hornblende than the normal variety. According to Falconer the picrite, which belongs to the Inchcolm type, occupies more than half the thickness of the sill. He describes the underlying teschenite as more nearly allied to the picrite than the overlying rock.

[1] Campbell & Stenhouse, Trans. Edinb. Geol. Soc., vol. ix, pt. ii, pp. 121–34, 1907.

[2] Trans. Roy. Soc. Edinb., vol. xlv, pt. iii, pp. 601–11, 1907.

TABLE III.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Plagioclase .	23·2	27·9	6·6	23·3	16·4	—	5·7	—	28·9	34·5
Orthoclase .	10·2	5·6	—	—	—	—	—	—	—	2·9
Analcite . .	16·1	19·9	12·2	—	—	13·4	8·8	—	13·8	15·5
Nepheline .	—	—	—	12·6	16·6	—	—	—	—	—
Titanaugite .	28·1	27·2	24·0	36·1	35·9	56·6	26·1	20·5	39·9	27·3
Hornblende .	—	—	18·1	—	12·2	12·7	8·6	10·0	—	—
Olivine . .	10·6	7·5	32·5	18·6	8·7	11·1	49·1	65·2	4·6	12·9
Biotite . .	3·4	1·5	3·7	3·6	6·7	—	·4	2·0	2·9	2·1
menite . .	7·1	9·3	1·9	4·2	2·5	5·1	1·0	2·3	9·9	3·7
Apatite . .	1·3	1·1	1·0	1·6	1·0	1·1	·3	—	—	1·1

I. Fine-grained banded teschenite, near upper contact, Bellow Water.
II. Teschenite, with abundant analcite, near upper contact, Bellow Water.
III. Melanocratic teschenite, below II.
IV. Theralite, below III.
V. Hornblende-theralite, below III.
VI. Augite-picrite, top of ultra-basic mass, Glenmuir Water.
VII. Olivine-picrite, top of ultra-basic mass, Glenmuir Water.
VIII. Hornblende-peridotite, main ultra-basic mass, Glenmuir Water.
IX. Teschenite, between base of peridotite and X, Glenmuir Water.
X. Teschenite, lower contact, Glenmuir Water.

Whilst some of the rocks from the upper contact contain nepheline, the theralite zone, so conspicuous in the Lugar sill, is absent.

Another picrite-teschenite complex is intruded as an intricately ramifying mass into the agglomerate of the Carskeoch vent, near Patna. Among the rocks represented here are picrite, teschenite, lugarite, monchiquite bearing huge crystals of hornblende and biotite, and essexite. Ultra-basic *couches* occur in the interior of some of the kylite sills, and will be described later under the head of kylite (see Part II).

4. *Lugarite.*—A very remarkable rock with affinities to the leucocratic teschenites and to the ijolites occurs in the heart of the Lugar teschenite-picrite complex as a sill about 4 feet thick, and as thin veins or dykes penetrating the picrite. In hand-specimens it has a very striking appearance. It generally shows a grey or greenish-grey groundmass crowded with lustrous black prisms of barkevicite ranging up to 3 inches in length, and frequently arranged in rude stellate groups. Shorter and stouter black crystals occur which are recognizable as augite. In thin section the rock is seen to be composed of analcite, nepheline, plagioclase, barkevicite, titanaugite, ilmenite, and apatite. The analcite (with nepheline) forms about 50 per cent of the rock, and is usually decomposed with the formation of a brown dust. It may be recognized by the fact that it occasionally clears to a limpid patch of undoubted analcite, and by the frequently complete analcitization of the enclosed felspars. Titanaugite and barkevicite occur as large euhedral crystals, the extraordinarily perfect forms of which testify to the freedom of their crystallization, and the liquidity of the magma in which they were developed. The augite is of a deep-purple colour with an intense pleochroism; the barkevicite is red brown, also with strong pleochroism. In the prevailing variety of the rock titanaugite occurs to the extent of 20 per cent, and

barkevicite 15 per cent. The felspar is also perfectly euhedral, and very zonal. The determination of its composition is difficult because of the analcitization it has undergone, but it is probably a labradorite of the usual composition—$Ab_1 An_1$. It forms about 10 per cent of the rock. Ilmenite passing over to leucoxene totals 3 per cent, and apatite, which crowds the groundmass, about 2 per cent. Nepheline occurs in the groundmass, but decomposition renders the recognition difficult. Its presence is indicated by a streaky micaceous alteration product, and by faint hexagonal or rectangular outlines occasionally discernible in the groundmass. The veins penetrating the Lugar picrite differ from the above in containing no titanaugite. The proportion of barkevicite and apatite is greater. Rocks closely resembling the above occur as schlieren, veins, and irregular patches towards the top of the exposure of theralite at Barshaw House, near Paisley. Recognizable nepheline is considerably more abundant, however, than in the Lugar rock, and there are numerous small crystals of ægirine. The Barshaw theralite here falls naturally into its place as the melanocratic facies of lugarite.

This rock stands apart from the recognized types of igneous rocks, and can be fitted with no current name. It has therefore been called *lugarite* after the type locality. As far as the analcite content goes it resembles the heronite of Coleman.[1] Considering its composition and its association with the Barshaw theralite, which closely resembles the Madagascan bekinkinites, lugarite evidently has affinities with the ijolites, and may be regarded as an ijolite in which the greater part of the nepheline has been displaced by original analcite, and in which barkevicite is a prominent constituent as well as augite.

A rock with some resemblance to lugarite, but with considerably more felspar, occurs at the upper contact of a great essexite-dolerite sill at Howcommon Quarry, Craigie.

5. *Monchiquite.*—A remarkable rock belonging to this group is found in association with a picrite-teschenite complex at Carskeoch Hill, near Patna. In hand-specimens it is black and compact, and carries numerous huge phenocrysts of hornblende and biotite ranging up to 3 inches in diameter. Microscopically it consists of a crowded mass of idiomorphic granules of pale augite, with numerous crystals of magnetite and flakes of biotite. Olivine occurs abundantly as small micro-porphyritic crystals. All these are enveloped in a scanty but pervading groundmass of analcite, which also occurs in numerous irregular areas where its specific characters may be easily recognized. It is partially carbonated, and the areas are surrounded by a thick zone of augite granules many of which are aligned tangentially to the margin. The phenocrysts consist of the above-mentioned large hornblendes, which are of a red barkevicitic variety, and biotite, also a red variety. A little red hornblende also occurs in the groundmass. The rock contains numerous ocelli of various kinds, the commonest being a simple radial aggregate of augite prisms.

This rock is very similar to the porphyritic monchiquite of Kilchattan, Colonsay.[2] It differs, however, in the presence of olivine

[1] Harker, *Petrology for Students*, 4th ed., 1908, p. 132.
[2] *Summary of Progress of Geological Survey for 1909*, 1910, p. 52.

and the absence of nepheline. An almost identical rock has been described by Boulton from the Old Red Sandstone between Chepstow and Usk, in Monmouthshire.[1] Rocks of monchiquitic habit and composition, but without porphyritic constituents, occur as the contact facies of some kylite and teschenite sills, notably at Craigie and Kilmaurs.

B. *Rocks with conspicuous Nepheline.*

Rocks belonging to this group occur in far less abundance than these characterized by analcite. They comprise theralites and essexites, with an almost ultra-basic type—kylite. The latter, and the essexites also, contain only a small quantity of nepheline, but are treated here because of their relationship to the conspicuously nepheline-bearing rocks.

1. Theralite. (a) *Bellow type.*—This rock has been mentioned in connexion with the teschenite-picrite sill of Lugar, in which it forms a stratiform mass, about 10 feet thick, intervening between the upper teschenite and the picrite. In hand-specimens the rock is grey to black in colour, and very fine-grained in texture. Microscopically it is composed of plagioclase, nepheline, titanaugite, olivine, biotite, ilmenite, and apatite in the proportions shown in Table III, column IV (p. 77). Augite is present in two forms—as innumerable minute prismoid grains embedded in the felspathic groundmass, and as larger euhedral pseudo-porphyritic crystals of a deep-purple tint. Olivine occurs in large, fresh, more or less rounded crystals full of magnetite-blackened fissures. Biotite, whilst forming numerous independent flakes, is also commonly associated with very irregular skeletal crystals of ilmenite. All these constituents are embedded in a groundmass of fresh anhedral felspar and turbid nepheline. The felspar is a highly zonal plagioclase, ranging in composition from $Ab_1\ An_1$ to $Ab_3\ An_1$. It is occasionally bordered by a little orthoclase. The nepheline is usually turbid owing to the development of a characteristic streaky micaceous alteration-product, which is arranged parallel to the cleavage. It builds rather large plates to which the felspar is idiomorphic. The felspar and nepheline are crowded with needles of apatite. The rock has a characteristic poikilitic fabric, the granular ferro-magnesian constituents being enclosed in the broad plates of plagioclase and nepheline. The felspars show systems of radiating fissures springing from enclosed olivine where the alteration of the latter has given rise to serpentine and consequent expansion.

Another variety (Table III, column V) shows a considerable development of barkevicitic amphibole, with a diminution of olivine and plagioclase and an increase in the amount of nepheline. This rock approaches the Barshaw type described below.

The rocks described above belong to the theralite group, but have a distinctly melanocratic facies as compared with typical theralites such as that of Duppau, Bohemia. They differ from the kylite group described below in the small proportion of olivine and the abundance of nepheline. Their textural peculiarities and mineral composition entitle them to rank as a distinct type, which may be named the *Bellow type*, after the stream in which they are best exposed. Some thin anastomosing veins penetrating the Bellow rock show the same

[1] Proc. Geol. Soc., 1911, p. 104.

constituents, with the addition of analcite; but the salic and femic minerals are here more nearly on an equality, as in the typical theralites.

Theralites of a more normal type occur at Garlaff and Knockterra, near Old Cumnock. In these there is approximate equality between the amounts of the salic and femic constituents. The deep-purple titanaugite builds large subhedral plates which ophitically enclose small laths of felspar. There is no granulitic generation of augite. Fresh olivine is fairly abundant. The nepheline is decomposed, but may be recognized by its characteristic alteration.

(b) *Barshaw type.*—Mr. E. B. Bailey has described a theralitic rock from a small sill at Barshaw House, near Paisley.[1] The chief femic constituents are titanaugite and dark-brown soda-amphibole, with sparse olivine and iron-ores. Labradorite and large allotriomorphic plates of nepheline form the remainder of the rock. The nepheline is mostly decomposed to various secondary products, chlorite, and analcite; but the latter may also be primary. The rock is decidedly melanocratic as may be gathered both from microscopic study and the chemical analysis.[2] The mineral constituents are the same as those of lugarite, but analcite is more abundant in the latter, which is undoubtedly the leucocratic facies of the Barshaw type. This conclusion is supported by the fact that towards the top of the Barshaw exposure occur contemporaneous bands and veins of lugarite; but the nepheline in this rock is much fresher and more abundant than in the type-occurrence of Lugar. The Barshaw exposure[3] also provides mesocratic types intermediate between theralite and lugarite. With an increase in the salic constituents, especially analcite, goes a significant increase in the idiomorphism of the titanaugite and barkevicite, which culminates in the very perfect forms displayed by these minerals in lugarite.

A rock which probably belongs to the Barshaw type occurs in the Inner Nebbock sill at Saltcoats, Ayrshire. Here, however, the felspar and nepheline have entirely disappeared, and fresh titanaugite, barkevicite, serpentinized olivine, and ilmenite are enclosed in a groundmass of brilliantly polarizing zeolites.

(*To be concluded in the March Number.*)

V.—The Fossil Flora of the Ingleton Coal-field (Yorkshire).

By E. A. Newell Arber, M.A., F.G.S., Trinity College, Cambridge, University Demonstrator in Palæobotany.

THE Upper Carboniferous rocks of the Ingleton Coal-field in North-West Yorkshire present a difficult study, and at the present time they are very imperfectly known.[4] As mapped by the

[1] *Summary of Progress of Geological Survey for 1908*, 1909, p. 44; also Mem. Geol. Surv., *The Geology of the Glasgow District*, 1911, p. 134.

[2] *Summary of Progress of Geological Survey for 1907*, 1908, p. 55. This rock is called "bekinkinite or theralite" by Bailey, Mem. Geol. Surv., *Geology of the Glasgow District*, 1911, p. 134.

[3] *Summary of Progress of Geological Survey for 1908*, 1909, p. 44.

[4] J. R. Dakyns, etc., *The Geology of the Country around Ingleborough* (Mem. Geol. Surv.), 1890. See also Davis & Lees, *West Yorkshire* (London, 1878), p. 167

Geological Survey,[1] there is apparently a perfect succession, passing up from the Yoredales, through the Millstone Grits, to the Lower and Middle Coal-measures. The coal-measures are in part overlain by a series of red rocks, which have been assigned to the Permian, as in the case of other of the Midland Coal-fields. In the index of the Survey map of the north-eastern portion of the coal-field, the Deep Coal is taken as the top of the Lower, and the bottom of the Middle Coal-measures.

So far as I am aware no fossil plants have hitherto been recorded from the coal-field.[2] The specimens discussed here are in the Sedgwick Museum, Cambridge,[3] and were collected during the visits of Professor Hughes' field classes to the district in 1886 and on other occasions. Another collection, formed by the donor from the same locality, has recently been presented to the Museum by Miss Elles. The plants occur both in the shales and also in the clay ironstone nodules, as is so commonly the case in the Midlands. They were chiefly obtained from the waste heap of Newfield Pits, Ingleton. The section of this colliery is published in the Survey Memoir.[4] The Coal-measures penetrated in these pits are only 114½ feet in thickness, and include the Crow, Main or Four Foot, and the Six Foot Coals. The specimens in shale presented by Miss Elles were obtained *in situ* from the shales forming the roof of the Six Foot Coal. The ironstone nodules no doubt occur in more than one bed. They are frequent in the so-called 'soapstone', or argillaceous shales, above the lowest seam. There is thus little doubt that all the specimens described here were closely associated.

The flora of these beds, though small, is of much interest. There is a considerable variety of fern-like fronds, including one belonging to *Sphenopteris*, which may be compared with *S. Laurenti*, Andræ, but which is not sufficiently well preserved to be determinable specifically. There are several Neuropterids, *Neuropteris acuminata* (Schloth.) being frequent. *N. heterophylla*, Brongn., *N. obliqua* (Brongn.), and *N. gigantea*, Sternb., also occur. Cyclopterid pinnules of the type of *Cyclopteris trichomanoides*, Sternb., are present. *Alethopteris* is probably represented by three species—*A. lonchitica* (Schloth.), *A. decurrens* (Artis), and *A. davreuxi* (?) (Brongn.). *Mariopteris muricata* (Schloth.) is frequent, and it is especially interesting to find that several examples of *Dictyopteris sub-Brongniarti*, Grand'Eury, have been collected, and that this plant appears to be of fairly frequent occurrence.

The Lycopods are represented by stems of *Lepidodendron obovatum*, Sternb., and *L. lycopodioides*, Sternb., as well as a large number of leafy twigs, some of which no doubt belong to the latter species. A single specimen of *Lepidophloios laricinus*, Sternb., is present.

[1] As is well known, this coal-field is intersected by four sheets of the Geol. Surv. Maps. Sheets N.S. 49 (= 98 S.E. of O.S.) and N.S. 50 (= 97 S.W. of O.S.), however, contain the greater part of the area of Upper Carboniferous rocks.

[2] Davis & Lees (ibid., p. 169), however, noticed the occurrence of fossil plants in the ironstone nodules of the Coal-measures.

[3] Carb. Plant. Coll., Nos. 1114, 1360–1, 1364, 1367–8, 1370–1, and 2178–2209.

[4] Dakyns, ibid., p. 81.

There are also several examples of *Lepidostrobus*, and, in some of the shales, masses of rootlets, of unknown affinity, are conspicuous.

The following is a list of the species which were recorded :—

FILICALES OR PTERIDOSPERMS.
Sphenopteris cf. *S. Laurenti*, Andræ.
Neuropteris acuminata (Schloth.).
N. heterophylla, Brongn.
N. obliqua (Brongn.).
N. gigantea, Sternb.
Alethopteris lonchitica (Schloth.).
A. decurrens (Artis).
A. davreuxi (?) (Brongn.).
Mariopteris muricata (Schloth.).
Dictyopteris sub-Brongniarti, Grand'Eury.

LYCOPODIALES.
Lepidodendron obovatum, Sternb.
L. lycopodioides, Sternb.
L. sp.
Lepidophloios laricinus, Sternb.
Lepidostrobus sp.

This flora is quite a typical Middle Coal-measure assemblage, and there is thus no doubt that the coals worked at the Newfield pits belong to that horizon. Several of the species are unknown from the Lower Coal-measures, especially *Alethopteris Davreuxi* (Brongn.) and *Lepidophloios laricinus*, Sternb. *Dictyopteris sub-Brongniarti*, Grand'Eury, have been recorded only from the Middle Coal-measures.

As a whole the Ingleton Coal-measures seem to be closely related to the Yorkshire Coal-field, and all the species recorded here, except *Dictyopteris sub-Brongniarti*, Grand'Eury, are already known from that coal-field.

VI.—New Devonian Fossils from Cornwall.

By Ivor Thomas, D.Sc., Ph.D., F.G.S.

(Communicated by permission of the Director of the Geological Survey.)

A SHORT time ago a Devonian fossil of considerable interest was found in the grits of the Ladock neighbourhood. It had been found by a workman in a road-heap on the Grampound Road and was placed for preservation in the Truro Museum. A cast was kindly made by Mr. C. Davies Sherborn and presented to the Museum of Practical Geology [22466]. This fossil was named *Orthis* sp., and is referred to as such in the Memoir of the Geological Survey on the geology of the country near Newquay (p. 35).

More recently Messrs. C. Davies Sherborn and Upfield Green were fortunate enough to secure another example of this Brachiopod from the Ladock quarry. Mr. Upfield Green succeeded through patient developing of the second specimen in exposing the muscle impressions of one valve, and this has justified the previous allocation of the specimens to *Orthis*. The second example has been presented by Mr. C. D. Sherborn to the British Museum (Nat. Hist.).

Though the preservation of the specimens leaves much to be desired, it is considered advisable to publish this note in order to induce further careful search in a locality hitherto considered to be practically unfossiliferous.

First example.—This shows the two valves in conjunction, with prominent umbones and well-developed area in the brachial valve. The latter has a broad sinus, due probably in part to deformation, as the opposite valve has no appreciable fold. The surface is ornamented with strong costæ, which are widely spaced, the breadth of each interspace being about twice the thickness of a costa. Smaller ones are occasionally interpolated. The middle of the anterior margin of the brachial valve has six costæ within a space of 10 mm., while the maximum length of the shell is 26 mm. and the maximum width 41 mm.

Second example.—This specimen does not show the costation so well as the preceding, though the anterior portion is somewhat better preserved. At the anterior part of the middle portion of the valve there are about eleven costæ within a space of 10 mm. The greatest length of the preserved part of the shell, consisting only of the brachial valve, is 23 mm., while the greatest preserved width is 52 mm. The fairly high triangular area lies in the plane of the shell, while the cast of two strong delthyrial supporting plates, imperfectly preserved, and an open delthyrium with a strong cardinal process are present. The process is produced forward as a strong median septum for a distance of about 16 mm. The adductor muscle-impressions cover a pear-shaped area and are divided into two portions by the median septum. Each of these portions is further subdivided by two longitudinal grooves, another groove forming the lateral and anterior boundary of each half of the muscular area. The whole muscle-impression has a maximum length of 17 mm. and a maximum width of 10 mm.

Both specimens are compressed along the longitudinal axis, so that the width-measurement is greater than in the original state.

Affinities.—No described form appears to agree with this species. The deformation of the examples makes comparison difficult, but they suggest nearest relationship to the robust form described by Professor Kayser [1] and Dr. Drevermann [2] from the Siegener Grauwacke as *Orthis personata*, Zeiler. The British form, however, is more coarsely costate and has a more rotund and less elongated muscular area in the brachial valve.

Locality and Horizon.—Mr. C. Davies Sherborn informs me that the first-mentioned specimen was obtained by a road-mender on a road-heap on the road to Grampound and about two miles south of Ladock. Other 'shells' were said to have been present with it on the same heap. The second fossil is in undoubted Grampound Grit matrix, and was found by a quarryman named Bennett in response to a reward offered by Mr. Upfield Green. Mr. Green was informed of the discovery by the Ladock schoolmaster, Mr. Clemmow. The quarry is on the west side of the river over the bridge from the inn.

Though there exists a certain divergence of opinion regarding the correlation of the Grampound Grit with beds of other localities, there is now practical unanimity in allocating it to a Lower Devonian horizon. Mr. Ussher [3] defines the term as a "name given to the

[1] E. Kayser, "Beiträge zur Kenntniss der Fauna der Siegenschen Grauwacke": Jahrb. d. K. p. geol. Landesanst., Bd. xi (1890), p. 98, pl. xi, figs. 3–5; pl. xii, figs. 1–4; Berlin, 1892.

[2] F. Drevermann, "Die Fauna der Siegener Schichten, etc.": *Palæontographica*, Bd. l, p. 264, pl. xxxi, figs. 1–8, Stuttgart, 1904.

[3] Mem. Geol. Surv., *The Geology of the Country around Bodmin and St. Austell*, Sheet 1" 347, p. 25, London, 1909.

arenaceous and conglomeratic rocks, which extend westward from Pentewan through Grampound, by me in 1890, from the descriptions of the type in De la Beche's Report, pp. 83 and 92, near Pentewan and Grampound". Messrs. C. Davies Sherborn and Upfield Green[1] consider the Grampound Grit to be equivalent to the 'Portscatho' of Mr. J. B. Hill[2] and correlate it with the Upper Gedinnian of the Continent. The Portscatho series is placed by Mr. Hill[2] in the Lower Palæozoics. Mr. J. H. Collins[3] was disposed in his earlier work to place the Ladock Beds in the Upper Silurian, but later[4] he appears inclined to assign them to the Lower Devonian. The correlation proposed by Mr. Green is questioned by Mr. Ussher,[5] who, however, agrees that the Grampound Grits are of Lower Devonian age and includes them in the Meadfoot Group.[6] They are also placed in the 'Lower Devonian' by Mr. Clement Reid,[7] but higher in position than according to Mr. Ussher's view.

It would be unsafe to attach too much weight to the evidence of the imperfect specimens above described, though their characters certainly suggest that the Grampound Grit was deposited during Upper Gedinnian or possibly 'Siegener Schichten' time.

REVIEWS.

I.—The Wealden Fishes of Belgium.

Les Poissons Wealdiens de Bernissart. By Dr. Ramsay H. Traquair, F.R.S. Mém. Mus. Roy. d'Hist. Nat. Belgique, vol. vi, pp. 1–65, pls. i–xii, 1911.

FOR many years palæontologists have eagerly awaited a description of the large collection of fossil fishes from the Wealden formation of Bernissart, Belgium, found associated with the remarkable skeletons of *Iguanodon* and other reptiles of which a preliminary account was published more than twenty years ago by Professor L. Dollo. The long delay, however, has not been altogether in vain; for the Brussels

[1] Upfield Green, "Note on the Correlation of some Cornish Beds with the Gedinnian of Continental Europe": Geol. Mag., n.s., Dec. V, Vol. I, pp. 403–7, London, 1904.

[2] J. B. Hill, "On the Relation between the Older and Newer Palæozoics of West Cornwall," Geol. Mag., n.s., Dec. V, Vol. III, pp. 206–16, London, 1906; Mem. Geol. Surv., *The Geology of Falmouth and Camborne*, Sheet 1″ 352, p. 33, London, 1906.

[3] J. H. Collins, "Preliminary Note on the Stratigraphy of West Cornwall," Trans. Roy. Geol. Soc. Cornwall, vol. x, p. 2, Penzance, 1879–87; "On the Geological Structure of the northern part of the Meneage Peninsula," ibid., p. 47.

[4] J. H. Collins, "On the Geological Age of Central and West Cornwall": Journ. Roy. Inst. Cornwall, vol. viii, pt. ii, p. 163, Truro, 1884.

[5] W. A. E. Ussher, "The Devonian Rocks of Cornwall": Geol. Mag., n.s., Dec. V, Vol. I, pp. 587–91, London, 1904.

[6] Mem. Geol. Surv., *The Geology of the Country around Bodmin and St. Austell*, Sheet 1″ 347, p. 2, London, 1909.

[7] Ibid., *The Geology of the Country near Newquay*, Sheet 1″ 346, pp. 30–5, London, 1906.

Museum has at last been able to obtain the services of Dr. Traquair for the work, and he has now accomplished it in a manner which only his experience, skill, and patience have made possible. The fossils are by no means in the best state of preservation for study, being crushed in a grey clay and not exhibiting the cranial osteology; but they are nearly three thousand in number, and they have been so exhaustively examined and compared by Dr. Traquair that the principal distinctive characters of most of the species are well made out.

The fish of perhaps the greatest interest is a new species of *Coccolepis* (*C. macropterus*), which is a typical member of the Palæoniscidæ, an ancient family not hitherto discovered above the Purbeck formation. Dr. Traquair publishes good restored figures of this important fish, showing both the internal skeleton of the trunk and an outer view, which lacks only the details of cranial osteology. It is the largest known species, except *C. australis* from the Jurassic of New South Wales; and its Acipenseroid pelvic fin-supports are clearly shown, as already described in this earlier form.

Of *Lepidotus* Dr. Traquair distinguishes three new species, and is able to publish a good restored figure of *L. bernissartensis*. There are also a few specimens of a small *Notagogus*, which seems to exhibit scales more cycloidal than usual.

The numerous specimens of Pycnodonts appear to belong to a single new species of *Mesodon* (*M. bernissartensis*), of which Dr. Traquair adds an especially interesting restored figure. He considers that the supraoccipital bone enters extensively into the cranial roof, widely separating the parietals, as in the highest teleostean fishes.

A species of Eugnathid fish is referred to *Callopterus*, a genus hitherto found only in the Lithographic Stone of France and Germany; and there are two species of an Amioid, apparently of the genus *Amiopsis*, which is typically Cretaceous, but may also be represented in the Purbeck Beds.

The occurrence of *Pholidophorus* is doubtful, though probable; and there are several specimens of *Pleuropholis* and *Oligopleurus*, which are too imperfect for satisfactory specific determination. Dr. Traquair thinks that the *Oligopleurus* may be identical with *P. vectensis* from the English Wealden.

Leptolepid fishes are also abundant, including three new species of *Leptolepis* itself, and one new species of *Aethalion*, of which two excellent restored figures, internal and external views, are given. The *Aethalion* is a large fish, bearing much resemblance to the so-called *Leptolepis valdensis* from the Wealden of Southwater, Sussex.

In conclusion Dr. Traquair summarizes his results, but refrains from expressing an opinion on the question as to whether the Wealden formation should be referred to the Jurassic or to the Cretaceous epoch. He might have added to the cited literature Professor Seward's determination of the Jurassic rather than Cretaceous affinities of the Wealden Flora. A comparative table of the species from Bernissart and those from the English Wealden is given, and the total absence of Selachian fishes in the Bernissart collection is specially noted. As Dr. Traquair himself remarks, geologists may deduce their own conclusions from his results; and we should add that zoologists too will find in the beautiful text-figure restorations much important material for generalizations. The actual fossils are represented on the plates by a series of photographs.

A. S. W.

II.—Geological and Topographical Maps: their Interpretation and Use. By Arthur R. Dwerryhouse, D.Sc., F.G.S., Lecturer in Geology in the Queen's University of Belfast. 8vo; pp. vii, 133, with 90 text-illustrations. London: Edward Arnold, 1911. Price 4*s.* 6*d.* net.

THIS work, intended as "A Handbook for the Geologist and Civil Engineer", is clear and concise, and illustrated (as the author tells us) mostly from actual districts in the British Isles, although the localities are only given in a few instances.

Commencing with a description of topographic maps, of the different scales adopted by the Ordnance Survey, and the methods of depicting the physical features, the author proceeds to give examples of the construction of sections from contoured maps, with a reminder that the miles represented along a road in a hilly country are longer than those on flat ground. The methods of constructing maps in lands where none exist are not dealt with, but the author gives instructions for rough surveys of small areas by means of the prismatic compass, in cases where more local topographic detail is wanted.

Turning to geological maps the various scales of those issued by the Geological Survey of the British Isles are duly noted, as well as the particular uses of the sheets issued with Drift and without Drift. Both editions, it may be remarked, are desirable in questions of water-supply and tunnelling, as Drift may be 200 feet or more in thickness. While the 6 inch maps are essential in practical inquiries, the 1 inch maps are rightly regarded as the most generally useful; and those which in recent years have been colour-printed have the advantage in most cases of a column of formations showing their relative thicknesses to scale, and of one or more longitudinal sections. The process of interpreting the structure and of drawing other sections is thereby greatly facilitated. For the latter purpose the 6 inch maps are desirable. In other cases the student may have to draw sections to ascertain the depth and thicknesses of strata from data given only on the geological map itself. Here knowledge is required not only of the sequence of the formations and of their thicknesses, but of unconformities. Some of these may be clearly marked; others, where for example Gault may rest on Oxford Clay, are only to be determined after close examination of the strata and their fossils. The many structural features in sedimentary and igneous rocks are explained and illustrated, including folds, faults, thrust-planes, flaws (fractures accompanied by horizontal movements displacing outcrops), and decussating folds (folded strata affected by later movements). The author rightly points out the need of paying regard to the general dip as opposed to local dips in the strata when dealing with the main geological features; and he further describes escarpments and dip-slopes, outliers and inliers, irregularities in thickness, lenticular beds, overlap, etc. When he remarks that

Gault is overlapped by Upper Greensand in the West of England, it should have been pointed out that the Gault in point of age is still represented in the basal sandy and loamy beds of the Upper Greensand.

From the descriptions and diagrams the student will soon grasp the relation of the rocks to the form of the ground and of outcrops to contours; and in a field-survey he will learn to complete his geological boundary-lines from the actual data observed along stream courses and scarps of rock, across tracts where the guides are mainly in the shape of the ground, and in the occasional outbreak of springs.

While the work, as implied in its title, does not deal with the variety of subjects of importance to the geological surveyor, such as are discussed in W. H. Penning's *Engineering Geology* (1880), in his *Text Book of Field Geology* (2nd ed., 1879), and in Sir A. Geikie's *Outlines of Field Geology* (5th ed., 1900), it will be exceedingly useful for study and reference on the interpretation, the uses, and method of construction of geological maps and sections.

III.—The Mount McKinley Region, Alaska. By Alfred H. Brooks; with descriptions of the Igneous Rocks and of the Bonnifield and Kantishna Districts, by L. M. Prindle. Professional Paper 70, U.S. Geological Survey, 1911.

In this quarto volume the authors have given a full account of what is known of the geology, physical features, and mineral wealth of the region, together with a history of previous explorations, and useful notes on the equipment necessary for the traveller. The climate, vegetation, and animal life are described, and it is pointed out that there is available a large amount of arable land, while the region also furnishes one of the best game-fields in Alaska.

The oldest rocks, which are probably pre-Ordovician, comprise schists, gneisses, quartzites, and subordinate limestones; then follow Ordovician (with graptolites), Silurian (?), Devonian (with corals, etc.), and Carboniferous (?). Triassic strata occur in Central Alaska, but not in the area now described. The Jurassic rocks contain andesitic and other lavas in the lower portions and some coal-seams (as yet undeveloped) in the higher strata. Cretaceous rocks are represented by limestone, black slates, and conglomerate. The Tertiary strata consist chiefly of freshwater beds belonging to the Kenai formation (Upper Eocene), and they contain important beds of bituminous and lignitic coals. There are also andesitic, basaltic, and rhyolitic lavas of post-Eocene and in part Pleistocene age, and extensive Pleistocene and Recent glacial and alluvial deposits.

The Igneous rocks are described by Mr. L. M. Prindle. The intrusive rocks are chiefly granites, granodiorites, and diorites. They occur in the Alaska range, where Mount McKinley rises to a height of about 20,300 feet, and in some other mountain tracts, including that of Talkeetna. There they appear to be mainly of late Jurassic age, but in other parts of Alaska some intrusions may be of Upper Carboniferous age, while others extend into Upper Cretaceous. There are no active or extinct volcanoes in the region.

Gold placer deposits are widely distributed in the Quaternary gravels, and there is a separate topographic map to illustrate the Yentna mining district. The gold has been derived from auriferous quartz-veins in the Birch Creek schists and other of the older metamorphic rocks. The andesitic lavas of Jurassic age also contain a little gold.

Some account is given of the past and present glaciation of the region, and Mr. Brooks remarks that "A rough estimate indicates that less than 1 per cent of the area formerly covered by ice still remains buried under glaciers and perpetual snow. The present glaciers appear to be rapidly retreating and represent the lingering remnants of the larger Pleistocene ice-sheets". He further observes that "The subject of ground ice is worthy of mention. It appears that on the south side of the Alaska Range the ground thaws out to bed rock every season. North of the range ground ice is nearly everywhere present under 1 to 2 feet of soil and humous matter. This layer remains frozen throughout the year. Usually where the alluvial material is undrained the permanent frost extends to bed rock, in one place 318 feet of frost having been measured. Locally, however, where loose gravels are encountered, the material is not frozen".

Hot springs are noted on the borders of the Tanana River, a tributary of the Yukon, in the Baker Gold Placer District.

It only remains to add that the work is illustrated by eighteen excellent pictorial views and maps, geologic and topographic, and by thirty text-figures.

IV.—Cambridge County Geographies.

FOUR additional volumes have been received of the Cambridge County Geographies. They comprise East London, by Mr. G. F. Bosworth; Monmouthshire, by Mr. Herbert A. Evans; the Isle of Man, by the Rev. John Quine; and Carnarvonshire, by Professor J. E. Lloyd.

East London is taken to include the boroughs of Islington, Stoke Newington, and Hackney on the north, and those of Camberwell, Lewisham, and Woolwich on the south. The volume is an interesting one, containing accounts of the parks, commons, and open spaces, of the rivers past and present, water-supply, geology (in brief), rainfall, industries, and many other matters. The illustrations are good, and include a view in Epping Forest, a fair on the frozen Thames in 1814, bridges old and new, Canonbury Tower, Staple Inn, Holborn, London Wall, and many others. Although Boulder-clay is mentioned in the text it is not present in the area; on the other hand, Blackheath Beds should have been noted, with Woolwich and Thanet Beds, on the geological map. This work has the advantage of an index, which is not the case with the three other volumes now before us. In these space is taken up unnecessarily by a full instead of a local table of geological formations, while in the volumes on Monmouthshire and the Isle of Man there are nearly three pages (alike in both) dealing with an explanation of geology. Mr. J. G. Wood has contributed local geological notes, all too brief, on Monmouthshire. He remarks that the Severn Sea lies in a great "trough fault", but this is not apparent from the geological survey map, although there is evidence of much faulting, folding, and unconformity. There are good views of the Usk and Sugar-loaf, of the Blorenge, and of the serpentine curves of the Wye. Agriculture, mines, and minerals are also dealt with. The alluvial levels bordering the Severn, locally known as "the Moors", are said to contain the deepest and richest soil in the county.

In the volume on the Isle of Man the geology is not satisfactory: it is remarked that "Underneath all rocks is the primeval granite, the foundation material of the earth's shell", and that the "very early granite" of Dhoon and Foxdale is covered by "Primary rocks, which may conveniently be termed Cambro-Silurian, i.e. of the same structure and formation as the Cambrian, the Ordovician, and the Silurian rocks of Wales". As the geological map at the end of the volume, based on that of the geological survey, gives these rocks as Manx Slates (Cambrian ?), the author might well have referred to the Survey memoir by Mr. Lamplugh to aid him in his geological descriptions, and he would then have learnt more about the "vast deposits of marl" beneath the surface in Kirk Andreas and Kirk Bride. In other respects the volume is full of interesting information, including remarks on place-names and surnames, antiquities, etc. The illustrations are effective, but those of Spanish Head, Calf Island, and Sulby Glen are not so clear as the picture of the Manx cat and many others. In the volume on Carnarvonshire the author acknowledges help from Mr. E. Greenly in the geological chapter, which is excellent though brief. Mines and quarries are separately dealt with, and there are views of the Penrhyn quarries. As remarked, there is a reduced demand for roofing-slate, as tiles are now more generally favoured by architects. Other views include the precipices of Carnedd Dafydd, Snowdon, Aberglaslyn Pass, Dolbadarn, and a group of black cattle. A concise history of the county may be mentioned among the many topics dealt with in this volume.

V.—Brief Notices.

1. Cotteswold Naturalists' Field Club.—In part ii of vol. xvii of the Proceedings of this Club (November, 1911), Mr. L. Richardson contributes a paper on "The Inferior Oolite and Contiguous Deposits of the Chipping-Norton District, Oxfordshire", describing in detail the succession of strata seen in many quarries in connexion with the 'Chipping Norton Limestone', so named by Hudleston in 1878. That limestone is newer than the *Clypeus* Grit of the Inferior Oolite, and represents the Lower Fuller's Earth; it is succeeded by a series of dark clays, together with marls and sandy limestones of estuarine character, to which the name 'Neæran Beds' has been given by Mr. E. A. Walford, while above comes the Great Oolite. In the Swerford area Mr. Richardson notes four subdivisions in the Chipping Norton Limestone, while elsewhere seventeen subdivisions are noted in the Neæran Beds. Local evidences of non-sequence between the Chipping Norton Limestone and beds above and below are indicated.

Mr. E. Talbot Paris describes and figures two new species of

Gervillia and one of *Perna* from the Neæran Beds. In further papers Mr. Paris contributes "Notes on some species of *Gervillia* from the Lower and Middle Jurassic Rocks of Gloucestershire", with text-illustrations and two plates, and a note on *Gervillia acuta* from the Scarborough Limestone. Mr. T. H. Withers gives a short note "On the occurrence of *Pollicipes* in the Inferior Oolite".

Mr. J. W. Gray deals with "The North and Mid Cotteswolds and the Vale of Moreton during the Glacial Epoch". In this article the author has discussed very fully the facts and opinions brought forward by various geologists. With regard to land ice he remarks that "There does not appear to have been any intrusion of these ice-sheets into the Cotteswold area, except, perhaps, the northern flanks and the Vale of Moreton"; and that "There are no signs of the passage of any of the great ice-sheets over the Cotteswold uplands". Some of the higher gravels are considered to have been "introduced by Tertiary streams that have been beheaded by the development of the Severn tributaries". The great accumulations of limestone-rubble on the Cotteswold slopes were probably due to "extensive snowfields liable to seasonal melting", as suggested by Witchell.

Although the Severn and Avon plain may have been subject to estuarine conditions during Pleistocene times, "there is no evidence that any of the gravels above a height of about 150 feet O.D. were laid down in an arm of the sea." Some of the marine shells, such as have been found at Cropthorne, may have been derived from Glacial beds in the Upper Severn valley. No evidences of Palæolithic Man have been found in the district described.

2. Mineral Resources of the Philippine Islands.—The Division of Geology and Mines, of the Bureau of Science, Manila, under the direction of the chief geologist, Dr. Warren D. Smith, has issued a report on the above subject (1911). The principal minerals are gold, silver, copper, manganese, and coal; and among other mineral products are building-stone, gravel and sand, lime and cement, brick and pottery clay. Occurrences of lead chromate, tin and zinc ores, platinum, and of beryl, spinel ruby, and garnet are recorded. The value of certain seepages of oil has yet to be proved. Gold occurs in placer deposits, and also in veins in igneous rocks (granite, gneiss, felsite, and decomposed andesitic rocks), in contact-zones with the sedimentary strata, and in fault-fissures. The sedimentary strata appear to be of Oligocene, Miocene, and later date. The granite and gneiss are regarded as probably pre-Tertiary or early Tertiary, the diorite-schist as probably pre-Tertiary. Some andesitic rocks are probably Miocene. The coal-bearing strata are grouped as Lower Miocene or Oligocene; there are four principal seams of variable quality, bituminous and gas-coal; and it is estimated that there are many million tons in the islands, although it is remarked that the inferior coals are found in some of the more accessible districts.

3. The Magdalen Islands.—Observations on these islands in the Gulf of St. Lawrence, by Dr. J. M. Clarke, have been published by the New York State Museum (Bulletin 149, Albany, 1911). They consist of "a chain of disjected and sea-wracked remnants of

continental land . . . fringed with sand spits and dunes and tied to one another by tremendous sand bars". They form, in fact, "a fearful menace to the sailor and his craft."

The rocks comprise hard grey or mottled schistose sandstones, with overlying purple-red sandstones, probably Permian; and at the base diabase in sheets accompanied by tuffs, and permeated by thin seams and sheets of gypsum, with also enormous gypsum beds intimately associated with the diabase. The lowest strata include, though they are but rarely seen, shales and limestones yielding goniatites and other fossils, of Carboniferous age. These are described by Dr. J. W. Beede, with a number of text-illustrations. Dr. Clarke remarks that in nearly every soil-section of the red rocks, there is a thin but persistent layer of pure white glistening sand, no doubt decoloured by organic acids. The islands have never been subjected to glacial action: they owe their preservation to slow elevation in later stages of their history.

The work is illustrated by a map and many views of rock scenery, including the Great and Little Bird Rocks, which afford nesting-places for gannets and other sea-fowl. There are also illustrations of sand-dunes and of the action of sand-etching on pebbles and boulders.

4. Professor A. C. Seward's *Links with the Past in the Plant World* (Camb. Manuals of Science and Literature, Camb. Press, 1*s*) is a popular discussion of the relative antiquity of existing plants and their distribution in past times as compared with the present, especially as illustrated by the ferns, the *Sequoias*, *Araucarias*, and *Ginkgo*.

5. Devonian Fauna of Wisconsin.—An important illustrated monograph on the fossils of the Middle Devonian of Wisconsin, U.S., has recently been published by Dr. Herdman F. Cleland in the Bulletin of the Wisconsin Geological and Natural History Survey, No. xxi. Prefaced with a brief sketch of the stratigraphy and a short bibliography, pp. 27–161 deal with the fossils, which are illustrated upon fifty-three excellent plates. The Cephalopoda are of special interest.

6. Oolitic Unios.—Mr. Wilfred Jackson has been paying especial attention to the figured types of Captain Thomas Brown and has had the good fortune to discover several of them among the miscellaneous fossils of the Manchester Museum. Of especial interest are two shells believed to be the originals of *Alasmodon vetustus*, Brown, from the Upper Estuarine Beds of Gristhorpe, Yorkshire. Mr. Jackson figures and discusses these in the *Naturalist*, 1911, pp. 104 seqq.

7. "The Resources of Tennessee."—This is the title of a monthly pamphlet issued by the State Geological Survey of Tennessee for the purpose of calling the attention of builders and others to the products of their own country adapted to their special requirements. No. 2 (August, 1911) is before us and deals with the Camden Chert as an ideal road material, the Ferndale iron-ore deposit, and cement materials in Tennessee. Three thousand copies are printed, and an appeal is made to the local Press to aid the work the Survey is attempting by reprinting the matter thus circulated.

8. Paul Choffat.—The friends of Dr. Paul Choffat will find a list of his geological publications in the Comm. Serv. Géol. Portugal, viii, 1911. It is conveniently divided into subjects and occupies 30 pages.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

December 20, 1911.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The President, in announcing the decease of Sir Joseph Dalton Hooker, O.M., at the age of 94, drew attention to the long connexion of that illustrious man of science with the Society, of which he was elected a Fellow no less than sixty-five years ago, in 1846; and stated that the Council had passed a resolution of condolence and sympathy, which had been forwarded to Lady Hooker. (See Obituary, Geol. Mag., January, 1912, p. 47.)

The following communications were read:—

1. "The Glacial Sections at Sudbury (Suffolk)." By the Rev. Edwin Hill, M.A., F.G.S.

The sections round Sudbury were described in two Geological Survey Memoirs: since the date of publication of these much more has been disclosed. A list is given of the principal sections now existing, with references to the descriptions in the Survey Memoirs and notes of those that are there undescribed.

The paper gives an account of a series of sands and silts, which lie at about 200 O.D. on each side of the present Stour Valley. They seem to indicate shallow-water conditions at a level more than 100 feet above the present valley-floor.

On the silts lies Chalky Boulder-clay. The transition from silt to clay is continuous, and seems to show that, here, the transition from formation of silt to formation of Boulder-clay was a continuous transition. The undisturbed condition of the beds indicates that during this transition there was no action of thrust or drag.

At lower levels, from 180 O.D. down to 100 O.D., on the flanks of the valley lie coarse gravels and sands, with current-bedding, which point to torrential water-action. Among these occur displaced masses of previously formed Boulder-clay, some contorted—as if by slip down slopes. At Little Cornard brickworks there is associated with current-bedded gravels a clay, in which are embedded very large masses of remade chalk.

The deduction from these facts is that at Sudbury, Boulder-clay began to be formed where there was quiet water, which stood on both sides of the valley at a level of over 120 feet above the present floor; and that, after such clay had been formed, there came to be strong currents into or along the valley, at various lower levels.

These deductions agree with the probable course of events, if a submergence preceded the Chalky Boulder-clay and an emergence followed it.

The Secretary read the following remarks received from Professor T. G. Bonney:—

"Unfortunately an engagement on Wednesday evening, made before I knew that this paper would then be read, prevents me from being present. That

I very much regret, since, as the author has taken me over all the sections (as I believe) described in his paper—in most cases two or three times at least—I should have liked to have expressed the opinions which I have independently formed. These are in full agreement with those set forth in his paper, so far as I can gather from the abstract. In the Sudbury sections at about 200 feet above O.D., a quite normal 'Chalky Boulder-clay' is seen overlying well-stratified silts and sands, with occasional false-bedding. These present every appearance of having been deposited under water, which was moving very gently and steadily. Their stratification shows no disturbance as it approaches the base of the Boulder-clay, and the latter does not in any way scoop or dig into it; but we find, not seldom, signs of a real, though rapid, transition from the one to the other.

"But, from about 180 to 100 feet O.D., that is more or less on the flanks of the Stour Valley (which the Glemsford boring has shown to be pre-Glacial)—sand, gravel, and Boulder-clay (normal) show great disturbance and strange associations—masses of the last material occurring in the others, like large irregular erratics. Their mutual relations are not suggestive of a ploughing-up by the snout of a glacier (which, had it deposited the Boulder-clay, would by this time have retreated from the district), but a downslipping of the older materials and a mixture of them with coarser gravels of more local origin.

"I may add that, sometimes in the author's company, sometimes with others, I have seen this orderly succession of silt, sand (more or less gravelly), and Boulder-clay, in other parts of the Eastern Counties, and not in them only. Thus, while I am fully conscious of the difficulties presented by the hypothesis of the subaqueous deposition of Boulder-clay, that which regards it as the direct product of an ice-sheet seems to me to involve yet more serious difficulties, at any rate in our Eastern Counties."

2. "The Ordovician and Silurian Rocks of the Kilbride Peninsula (County Mayo)." By Charles Irving Gardiner, M.A., F.G.S., and Professor Sidney Hugh Reynolds, M.A., F.G.S.

The Kilbride Peninsula includes three principal groups of rocks. The northern and western part is, in the main, composed of igneous rocks, contemporaneous and intrusive, of Arenig age; the southern and eastern part principally consists of Silurian rocks, but these are in the south-eastern corner of the peninsula faulted against an area of gneiss. The Arenig rocks resemble the Mount Partry Beds of the Tourmakeady and Glensaul districts—in the fact that they include cherts and shaly beds with *Didymograptus extensus*, and in the presence of gritty tuffs and coarse breccias, the latter rocks showing a magnificent development. No coarse conglomerates, however, occur, and no limestone breccias or other representatives of the Shangort Beds of Tourmakeady and Glensaul, while Arenig sediments of all kinds are very scarce. The most interesting feature of the Arenig rocks is the great development of spilitic lavas, which are commonly associated with cherts and often show good pillow-structure. Their resemblance to the similar rock of the Girvan district is very close. An enormous mass of felsite with large quartz-phenocrysts, and often albite, as also pseudomorphs after rhombic pyroxene, occupies much of the northern part of the peninsula. There is no doubt that it, like the similar masses of Tourmakeady and Glensaul, is of Arenig date. The Silurian rocks consist principally of grits, sandstones, and calcareous flags, and dip with great regularity in directions varying from south to east. The calcareous flags (Finny School Beds) are highly fossiliferous, and have yielded over fifty species, principally of corals and brachiopods, which prove the beds to be of Llandovery age.

Ill-preserved specimens of *Monograptus vomerinus*, found in the highest Silurian strata exposed, show that these are of Wenlock age.

Probably in early post-Silurian times occurred the intrusions of keratophyre and labradorite-porphyrite which are met with at, or near, the base of the Silurian. Then followed a period of important earth-movement, connected in all probability with the Caledonian movements in other regions. The area was folded into a syncline, the axis of which ran roughly north-east and south-west; and, perhaps owing to the rigid mass of felsite in the northern part of the peninsula, the Silurian rocks in adjusting themselves became traversed by numerous cross-faults. At some latter period intrusions took place of numerous small dykes and sills of dolerite.

Dr. Henry Woodward, F.R.S., supplies an Appendix giving a description of a new species of *Caryocaris* (*C. kilbridensis*).

II.—Mineralogical Society.

Anniversary Meeting, *November* 14, 1911.—Professor W. J. Lewis, F.R.S., President, in the Chair.

R. H. Solly: Dufrenoysite, associated with seligmannite from the Binnental. In a small cavity, discovered in August, 1911, in the dolomite rock in the Lengenbach Quarry, were a few brilliant crystals of dufrenoysite, coated on their fractured surfaces with minute crystals of seligmannite. Measurements of two crystals of the former led to the discovery of twenty-six new forms. — H. G. Smith: A simple graphic method for determining extinction angles in sections of biaxial crystals. A means of drawing a crystal projected on any plane and finding the extinction directions was explained.—Dr. G. T. Prior: On the Meteoric Stone which recently fell in Egypt. A meteorite fell on June 29, 1911, near the village of Abdel Malek, about 44 km. E.S.E. of Alexandria. It exhibits a brilliant, varnish-like crust, and consists mainly of a coarse-grained crystalline aggregate, without chondrules, of a green pyroxene, and a brown ferriferous olivine, with only a little felspar and practically no nickeliferous iron. A quantitative analysis showed that the stone included a high percentage of lime, and that the green pyroxene, containing much lime as well as ferrous oxide and magnesia, constitutes about three-quarters of the stone by weight. A study of thin sections under the microscope showed that the pyroxene is generally twinned on 100, gives extinction angles as high as 35°, and exhibits 'herring-bone' structure owing to fine twinning on 001.—T. Crook and S. J. Johnstone: Strüverite from the Federated Malay States. A mineral of doubtful identity found in the course of tin-mining on the Sebantun River, Kuala Kangsar district, Perak, was proved to be strüverite; it closely resembles the mineral recently recorded by Hess and Wells from South Dakota, U.S.A.—A. Hutchinson: On the temperature at which gypsum becomes optically uniaxial. A small plate of gypsum, cut normal to the acute bisectrix, was placed in a glass-topped cell, through which a stream of water at a determinate temperature was passed, and the optic picture was studied under a microscope. The plate became uniaxial at 95° C.—A. Hutchinson: On a total-reflection diagram. From this diagram the refractive index of a substance is graphically determined when given the angle of total reflection with respect to a known substance of higher refractive index. By taking the sine of the angle as co-ordinate the curves are straight lines.—T. Crook: The occurrence of Ankerite in Coal. The white crystalline layers often found as infillings of the vertical joints in British coal are ankerite. Dolomite was not found and calcite occurs sparingly as compared with ankerite in the specimens examined.

CORRESPONDENCE.

THE WEALDEN FISHES OF BERNISSART.

Sir,—I greatly regret that the names of new species described by me in my recently published work on the *Wealden Fishes of Bernissart* (Mém. du Musée roy. hist. nat. Belgique, May, 1911) have been antedated by three years.

The cause of this was that the plates, which contain the explanation of the figures as well as the figures themselves, were printed off in 1908, it being expected that the work would be published in the same year. Unfortunately my MS. was not ready in time, and publication was delayed until last year, and then, in going over the proofs, I ought to have corrected the dates in the letterpress, inserting a note of explanation of the matter. Here I committed the mistake of imagining that the date 1911 on the title-page cancelled the date 1908 in the text and on the plates, never thinking that the reader would thereby be led to suppose that these new specific names had already been published in a preliminary Note, which is not the case, and the proper date of publication of the names in question is May, 1911.

Ramsay H. Traquair.

Colinton, Midlothian.

HUMAN ART IN THE RED CRAG.

Sir,—In his recent communication [1] to the Royal Society Sir E. Ray Lankester gives an account of the discovery, *below* the Red Crag of Suffolk and the Coralline Crag, of human tools—flint implements. If there were tool-using men living while the basal deposits of the Red and Norwich Crag were being laid down, we should not find it hard to believe that there were men living while the mass of the Red Crag was deposited! Consequently the position taken up by the late Henry Stopes as early as 1881 is vindicated. In that year he read a short paper before the British Association, giving an account of a remarkable shell, engraved with a rude portrait of the human face, found in the stratified deposits of the Red Crag.[2] At that time

[1] See Geol. Mag., December, 1911, p. 576.
[2] H. Stopes, "Traces of Man in the Crag": Brit. Assoc. Rep., 1881, p. 700.

no one would accept the idea that man was living at so early a date, and the important discovery was practically ridiculed. In 1887[1] Henry Stopes wrote in the preface to a printed lecture, "I have afforded the scientific world matter for laughter for some years. My turn to laugh is surely and rapidly coming, for man will most certainly be proved to be as old as the Crag."

Owing to his early death he published little of the great works he planned, and the remarkable nature of his divinations and his laborious amassing of facts have never been fully recognized; but in this present year, when his prediction regarding the contemporaneous existence of man and the Red Crag fossils is established by others, it is worth recalling the facts about the fossil-portrait—the oldest work of art in the country.

The engraved shell is a specimen of *Pectunculus glycimeris*, a very common species in the Crag. It is naturally bored near the hinge by a small circular hole, which may have given its initial value to the first maker of miniatures. The shell's concave surface has five deep-cut marks, viz., two eyes, circular; a large nose, triangular; a wide mouth, slightly curved, with below it a small, nearly straight mark for a lower lip or chin. The portrait of humanity, though crude, is unmistakable.

The following points should be noticed. The rough surface of these incisions is of exactly the same colour as is the rest of the shell—a bright red-brown; while a fossil surface of this colour cut into to-day is white. Furthermore, this colour is as firmly established as the rest of the shell colour. My father submitted it freely to test, and allowed Mr. E. T. Newton to test it exhaustively. Mr. Newton said in 1897 in his presidential address to the Geologists' Association (p. 75), "The colour of the engraved portions is as firm as that of the rest of the shell."[2] He hesitated, however, to accept the shell as proof of the existence of man in Red Crag times.[3]

Now, however, that implements have been found, and Mr. Stopes' prophecy come to pass, the shell should be accorded its proper place among works of Palæolithic art. It is the first recorded Palæolithic drawing, for though the *Times* in 1885 gave credit to a Frenchman for the first discovery of such early traces of man, Mr. Stopes had read his paper before the British Association in 1881.

Marie C. C. Stopes, D.Sc. (Lond.), F.L.S.

14 Well Walk, Hampstead Heath, N.W.

[1] H. Stopes, "On the Antiquity of Man": paper to the Dulwich Eclectic Club, 1887.

[2] E. T. Newton, "The Evidence for the Existence of Man in the Tertiary Period": Pres. Add. Geol. Assoc., 1897.

[3] [Mr. E. T. Newton, after dealing *very fully* with the evidence, said in conclusion, "I am afraid there is too much doubt hanging over this carved Crag shell to allow us to accept it as definite evidence of Tertiary Man."—Presidential Address to the Geologists' Association delivered February 5, 1897: Proc. Geol. Assoc., vol. xv, 1897–8 (1899), p. 76.—Ed. Geol. Mag.]

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HENRY WOODWARD, LL.D., F.R.S., F.G.S., &c.

ASSISTED BY

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MARCH, 1912.

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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. III.—MARCH, 1912.

ORIGINAL ARTICLES.

I.—A Note on some Fossil Plants from the Kent Coal-field.

By E. A. Newell Arber, M.A., F.G.S., F.L.S., Trinity College, Cambridge, University Demonstrator in Palæobotany.

(PLATE V.)

THE rapid exploration of the Kent Coal-field during the last few years has considerably increased our knowledge of the very interesting Upper Carboniferous floras there developed. In a previous paper[1] I described the plants obtained from the Waldershare and Fredville borings, and I hope before long to publish further accounts of the floras derived from several other borings. In the present note I wish to draw attention to the discovery of two fossils in Kent which appear to me to be of exceptional interest.[2]

Dictyocalamites Burri, gen. et spec. nov. (Pl. V, Figs. 1, 3, and 5.)

Two examples which appear to be members of a new genus, allied to *Calamites*, have been obtained from cores of 4 inches in diameter at the boring at Barfreston, at a depth of 2,559 feet, on the property of the Sondage Syndicate, Limited. Impressions of true Calamites are also associated. The larger fragment of the new plant is shown on Pl. V, Fig. 1, enlarged to nearly twice natural size. Part of an internode is seen with a node above, the internode being 4 cm. long and 5 cm. broad, though it is not complete. The most striking feature of the fossil is the reticulate series of ridges of the internode, which, so far as I am aware, are quite unlike anything hitherto described. These anastomosing ridges are more clearly seen on Pl. V, Figs. 3 and 5, which are enlarged views of other fragments of internodes on the same piece of core. The ridges anastomose at infrequent intervals, forming elongately fusiform reticulations. The internodes exhibit a number of large, more or less irregularly oval, pits or depressions (Figs. 3 and 5) which obviously deflect the course of the ridges in their neighbourhood. I am inclined to regard these as the points of attachment of adventitious roots. One such root is seen apparently in continuity with the stem. This is not, however, shown in the photograph. Two of the root insertions are, however, plainly seen in Fig. 3 and one in Fig. 5.

[1] Arber, Quart. Journ. Geol. Soc., vol. lxv, p. 21, 1909.

[2] [For review of Geological Survey memoir on the Kent Coal Exploration, just issued, see *infra*, p. 131.—Edit.]

The nodal region is unfortunately very imperfect, though there can be little or no doubt that the upper part of Fig. 1 really represents a node, or that the ridges of successive internodes alternate. No reliable evidence exists either of infranodal canals or of leaf-scars. As to the interpretation of the specimens, it is of course difficult to draw any definite conclusions from the present material. The anastomosing of the ridges of the internodes is, however, a perfectly definite feature, though one would wish for more perfect examples of the nodes in order to determine whether these specimens represent the external impressions of a stem, or the pith-casts of a plant allied to *Calamites.* I am inclined to adopt provisionally the former view. The evidence of roots and of root-scars favours the suggestion that we are dealing here with the external surface of a stem. The absence of infranodal canals, though not conclusive in the present material, also supports this conclusion, so far as it goes.

The external surfaces of Calamite stems are very varied. Some are almost smooth, while others possess ridges and grooves on the internodes, not very dissimilar to those of the pith-casts. The interpretation of these specimens as external impressions, characterized by a reticulation of ridges on the internodes, naturally presents less difficulties than the supposition that we are dealing here with pith-casts. On the latter hypothesis, we should be led to imagine that the vascular bundles of this plant must have anastomosed frequently, as exhibited by the lozenge-shaped areas between the ridges. This is quite contrary, of course, to any evidence we have from petrified specimens. I think a new generic name, *Dictyocalamites*, may be proposed for such fossils, whether they eventually prove to be external surfaces or pith-casts.

The following is a diagnosis of the new genus: Segmented casts or impressions of Equisetalean affinity, similar in habit to those of *Calamites*, the internodes of which are characterized by a reticulation of ridges.

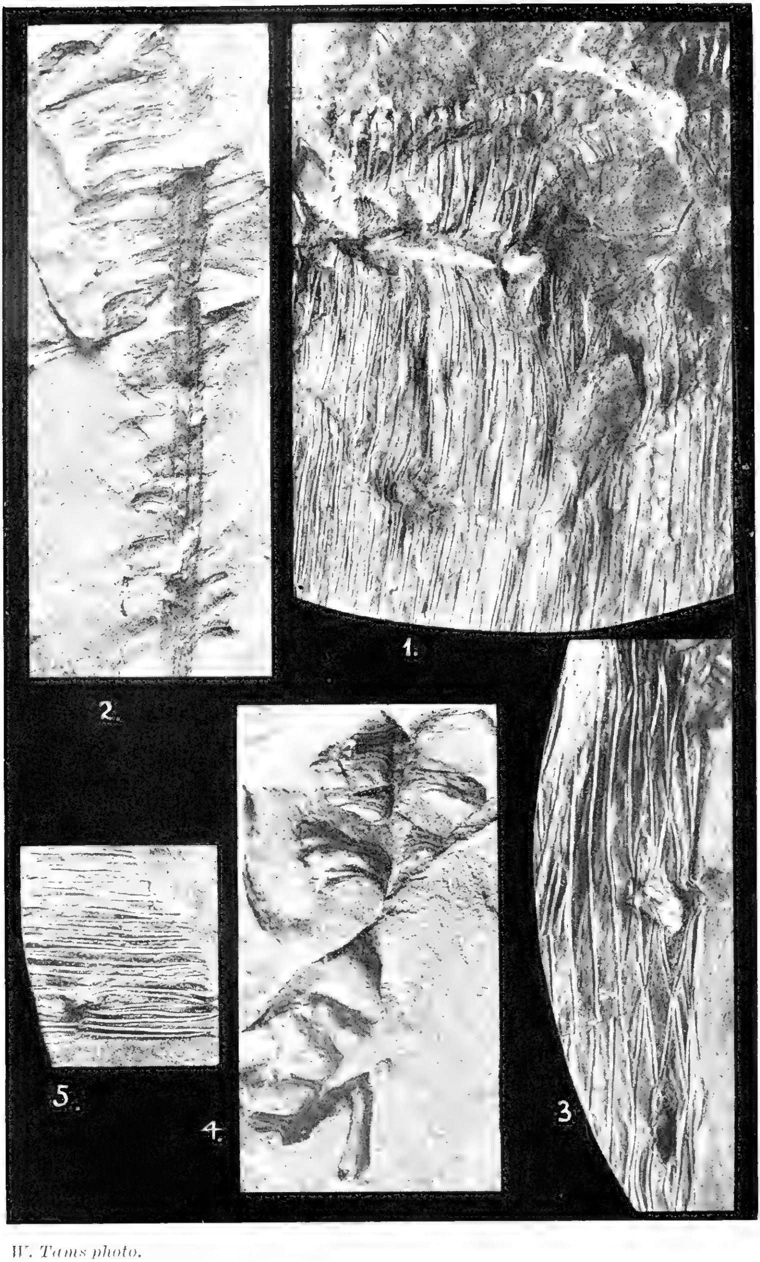
I have pleasure in naming the species after Dr. Malcolm Burr, F.G.S., who has very kindly presented the specimens figured here to the Sedgwick Museum, Cambridge.

PTEROPHYLLUM sp. (Pl. V, Figs. 2 and 4.)

The other new plant, which is of nearly equal interest, is represented by some fragments of leaves, which appear to belong to the genus *Pterophyllum.* They were obtained from the same boring at Barfreston, at a depth of 1,834 feet, in the Transition Coal-measures.

The two specimens figured on Pl. V, Figs. 2 and 4, show a somewhat stout rachis with fragments of pinnules still attached. None of the latter, however, are complete. The longest leaflet, slightly exceeding 1 cm. in length, is seen at the top of Fig. 2, which is enlarged nearly twice. The leaflets are fairly distant from one another, from 1 to 1·5 mm. broad, and appear to be slightly contracted at the base. Each has three or more parallel nerves, which fork occasionally near the base. These are seen on Fig. 4, which is three times enlarged.

There appears to be little doubt that these leaves are of Cycadophytean affinity. I have shown them to Professor Nathorst and



W. Tams photo.

Dictyocalamites and *Pterophyllum* from the Kent Coal-field.

other palæobotanists, and they agree with me in this conclusion. I believe them to be members of the genus *Pterophyllum*, one of the earliest types of leaf belonging to members of this alliance, appearing first of all in Carboniferous times. They may be compared with *Pterophyllum blechnoides*, Sandb.,[1] from the Stephanian of the Black Forest. Other species of this genus are known from the Stephanian and Permian of other parts of Germany, and especially from France. Fronds of this type are also abundant in the earlier Mesozoic rocks.

The occurrence of a *Pterophyllum*, even although the fronds are too fragmentary to warrant specific determination, in beds containing a typical Transition Coal-measure flora, is a quite unique experience in England, and, so far as I am aware, in the Westphalian rocks of Europe. Such rare cases illustrate the first slow incomings of the Cycadophyta, a group which reached its maximum during the Mesozoic period. The transition from the Palæophytic to the Mesophytic type of flora was probably a perfectly gradual one. The Mesophytic types begin to appear towards the close of the Palæozoic period. They come in very gradually, but become more numerous as we pass up through the Permian. It is not until Triassic times that they occupy the position of a dominant group. The rare occurrence of such a type of frond as *Pterophyllum*, one of the earliest known Cycadophytean fronds in the Stephanian and Permian, is thus of interest, and it is now satisfactory to find that this genus can be traced back as far as the Westphalian.

In this connexion it is interesting to recall the fact that a single twig of *Walchia imbricata*, Schimper, a plant of obvious Coniferous affinity, was described some years ago by Dr. Kidston[2] from the Upper Coal-measures of the Hamstead Colliery, Great Barr, near Birmingham. Here, again, we have one of the earliest evidences of the incoming of another great Mesozoic group, the Coniferæ.

EXPLANATION OF PLATE V.

The numbers refer to the Carboniferous Plant Collection of the Sedgwick Museum, Cambridge.

FIG. 1. *Dictyocalamites Burri*, sp. et gen. nov., showing a node and part of an internode which has reticulated ridges. No. 2259. From the Barfreston boring, Kent, at 2,559 feet. $\times \frac{9}{5}$.

,, 2. *Pterophyllum* sp. A portion of a leaf showing the stout rachis to which fragments of leaflets are attached. No. 2220. From the Barfreston boring, Kent, at 1,834 feet. $\times \frac{7}{4}$.

,, 3. *Dictyocalamites Burri*. Another portion of an internode, enlarged, showing the reticulating ridges and (?) scars of adventitious roots. No. 2224. From the Barfreston boring at 2,559 feet. $\times \frac{9}{5}$.

,, 4. *Pterophyllum* sp. Another fragment of a leaf in which the pinnules are somewhat more perfect. No. 2221. From the Barfreston boring at 1,834 feet. $\times 3$.

,, 5. *Dictyocalamites Burri*. A portion of another internode, showing the ridges and a (?) scar of an adventitious root. No. 2224. From the Barfreston boring at 2,559 feet. $\times \frac{9}{5}$.

[1] Sandberger, *Verhandl. Naturwissen. Verein Karlsruhe*, vol. i, p. 30, 1864.
[2] Kidston, Trans. Roy. Soc. Edinb., vol. xxxv, pt. vi, p. 324, pl. i, fig. 9, 1891.

II.—On the Interglacial Gravel Beds of the Isle of Wight and South of England, and the Conditions of their Formation.[1]

By Professor Edward Hull, M.A., LL.D., F.R.S.

(WITH A FOLDING MAP, PLATE VI.)

Part I: Introduction.

Previous Authorities.—The most important work dealing with my subject is that by Mr. Thomas Codrington "On the Superficial Deposits of the South of Hampshire and the Isle of Wight".[2] In this elaborate essay, which includes all the area with which I propose to deal, the author describes the gravel terraces on both sides of the Solent, including the New Forest, showing how they were originally distributed over surfaces gradually sloping downwards on both sides towards the margin of the sea-coast from a height of about 420 feet on either hand. In the author's view, the plateau gravel beds were spread as sheets over sloping surfaces, themselves intersected by river-valleys which were widened and deepened at a subsequent period after the deposition of the beds of gravel, so as to leave abrupt faces and cliffs exposing sections of the strata. The paper, which is illustrated by sections, leaves nothing to be desired for completeness; but in order to account for the deposition of the gravel-beds he propounds a theory which I am unable to accept. It is contained in clauses 3 and 4 of the Summary (p. 549), which I here quote at length:—

"3. The spreading out of the gravel, and the levelling of the tablelands, was probably effected in an inlet of the sea shut in on the south side by land which connected the Isle of Wight with the mainland, and opening to the eastward."

"4. A gradual elevation appears to have gone on from the time of the oldest and highest gravels down to the date of the low-level gravel-beds, by which the inlet was narrowed into an estuary which received the waters of all the rivers from Poole Harbour eastward; the Isle of Wight being still connected with the mainland."

From the above quotations it will be seen that the author refers the presence of the gravels to a very local origin, and assumes the formation of a gulf by the uprising of a sort of barrier between the extreme westerly end of the Isle of Wight and the mainland. But I am unable to recognize the evidence of such an uprise of the strata. The strike of the beds from the Needles to the Isle of Purbeck is nearly E.–W. and seems to exclude the idea of a land connexion at a time when, according to Mr. Codrington's own hypothesis, there must have been a deep submergence amounting to over 420 feet. The explanation I have to offer embraces a larger area of more general conditions. At the same time I agree with the author I am quoting, that the plateau gravels are of marine origin, deposited during a gradual uprising of the land from a level of about 420–50 feet above the present sea-surface.

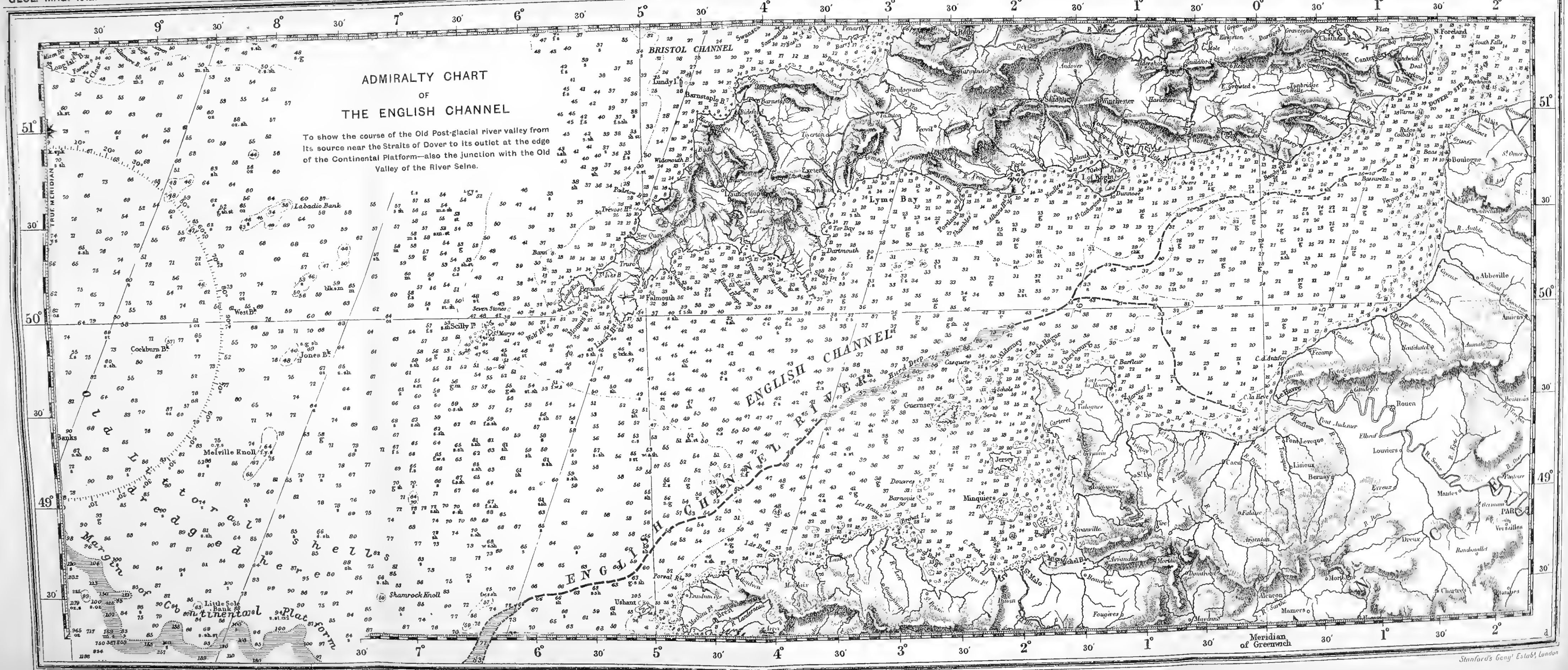
[1] Communicated to the Geological Society of London, November 8, 1911.
[2] Quart. Journ. Geol. Soc., vol. xxvi, 528, 1870.

In the Geological Survey Memoir by the late Mr. Bristow (second edition, by Messrs. Clement Reid and Aubrey Strahan, 1889) the plateau gravels are again described very much as done by the previous author, but necessarily more in detail. They are recognized by the authors as of great antiquity, and that since their deposition they have been traversed and broken into by the rivers on both sides of the Solent. But the authors do not appear to have arrived at any clear view regarding their origin and mode of formation, and in one case where the gravel is abruptly broken off at the edge of the Cliff above Alum Bay, the attempt to account for it is apparently abandoned as hopeless. I hope to be able to show that its position can be clearly accounted for.

Part II.

Terraces.—I may here be allowed to interpose a note regarding the physical features which we call 'terraces', or under the French form we call 'plateaux'. There are no more certain indications of changes of level under various conditions than terraces, whether by the sea-coast, the borders of lakes, or of rivers; and wherever I have gone I have studied their conditions with special interest. I have observed their position and relative levels along the coast of the British Isles, in England, Scotland, and Ireland; along the borders of the Mediterranean, and the banks of the Nile, the Dead Sea, and the River Jordan; in all these countries they indicate the levelling effects of the sea, the lake, or the river, at successive periods; and they are evidence of former submergence. It is from such evidence that we draw the inference that (as Mr. Codrington has correctly inferred) the coast of Dorset and the Isle of Wight has been submerged to a depth of over 420 feet. But having regard to the permanent level of the ocean waters, is it conceivable that this submergence was confined within the limits of this area alone? Why should it not have extended in all directions as far as the hills and uplands, rising into higher altitudes to the north, west, and east? For it cannot be questioned that the physical features of this region had been determined before the period when the plateau gravel beds were being accumulated.

Isle of Wight: Evidence of an Ancient Sea-margin.—Some few years ago, when on a visit to this island, with the aid of an aneroid I spent my time in making observations of level, and, amongst other places, I took the level of a gravel-bed at the summit of the cliff overlooking Alum Bay, and also of the remarkable gravel terrace south of Newport known as St. George's Down. My interest was greatly aroused on discovering that the aneroid readings were very nearly the same in both cases—approximating to 400 feet above the sea, or a little under. It then occurred to me that we had in these readings evidence of the existence of an ancient sea-margin. On ascending to the top of the St. George's gravel-pit, I found myself on a nearly level terrace extending far westwards, and breaking off in an abrupt cliff on the north and west sides. The beds were found to consist mainly of rolled chalk-flints, rudely but distinctly



Soundings in fathoms. Length of submerged channel nearly 300 miles.

Stanford's Geog! Estab! London

ENGLISH CHANNEL RIVER-VALLEY

(TO ILLUSTRATE PROF. HULL'S PAPER).

stratified. The section of the gravel cliff is fully described in the Survey Memoir.[1]

The gravel-bed on the summit of the cliff above Alum Bay is distinctly visible from the deck of the ship anchored in the bay below; and its horizontal stratification, resting on the nearly vertical strata of the Tertiary Series, forms one of the most interesting geological features of the country. Its presence there is easily explained. It once extended westwards to an undefined distance, but with the underlying Tertiaries it has been worn back along the side of the ridge of the Chalk, which now stretches to the Needles, but once extended to a greater distance towards the Isle of Purbeck. The Chalk ridge at the Tennyson Monument rises to a level of 483 feet, or somewhat under 100 feet above the level of the gravel beach from which the flint pebbles were derived by ordinary wave action. It is impossible to conceive of a more excellent example of the production of shingle at the base of its cliff at a former epoch, such as we are able to observe along our coasts at the present time.

Part III.

Dorset and the South of England.—It is unnecessary for me to describe at any length the plateau gravels, as they have been so fully described by Codrington and the officers of the Survey, while they are represented on the 1 inch Survey Map. That there are numerous deposits of sand and gravel at low levels along the coast of Southampton Water and the Solent is well known, and they are of peculiar interest as containing evidence of man's presence and of extinct animal remains. But what concerns us most in regard to the present inquiry is the upper limit of the plateau gravel beds to be found in the New Forest at levels corresponding very closely to those in the Isle of Wight. By way of illustration I shall refer to one or two examples visited by myself on the occasion of a recent visit with members of the British Association. Lyndhurst Church stands on Tertiary beds, at a height of 139 feet, but to the north and west the ground rises gradually, and on reaching Stony Cross Plain at a height of 373 feet we find ourselves on the margin of an extensive terrace, rising at Long Cross Plain to a height of 414 feet, but sloping gradually, in the direction of the River Avon, to the west; the average level is about 350 feet. The plain is formed of beds of gravel composed chiefly of rounded flint-pebbles and occasional bands of sand, and numerous shallow sections are supplied by the pits which are worked for road-stone to a few feet from the surface, which extends unbroken to the edge of the valley of the Avon and its tributaries. It is impossible not to recognize the similarity of the conditions on both sides of the Solent, though separated by an interval of about 25 miles. In each case we have beds of rolled flints, spread out in sheets with flat, or slightly inclined, surfaces, and reaching levels of nearly 400 feet above the sea, from which they descend by gentle slopes to the sea-margin. The origin of the flint-pebbles is beyond

[1] *Geol. Isle of Wight*, 2nd ed. The correct level of the upper surface of St. George's Down, as given in the Ordnance Map, is 365 feet. Probably that of the cliff at Alum Bay is somewhat lower.

question, and is to be found in the uplands of the Chalk formation, rising in the case of the Isle of Wight into the ridge which stretches from the Needles to Foreland Point, and in the case of the mainland rises into the great expanse of Salisbury Plain. These formed the land-margins of the area at a period of depression to the extent of over 400 feet. The epoch of this depression is not difficult to determine. That it was post-Tertiary is clear from the relations of the plateau gravels of the Tertiary beds as seen in the Isle of Wight, and it was after the period of disturbance which raised the Cretaceous and Tertiary beds into their present inclined position, and subjected them to an enormous amount of erosion. Thus we arrive at the conclusion that the plateau gravels are the representatives in the South of England of the Interglacial sands and gravels of the centre, east and north of England and Wales.[1]

Part IV.

Having thus endeavoured to show that the plateau gravels were deposited under the waters of the sea, and that the materials of which they are composed were derived chiefly from the erosion of the adjoining unsubmerged Cretaceous lands during an epoch of depression, it becomes necessary to refer back to the preceding epoch, in order to determine the physical changes which led up to succeeding conditions, and on this subject the evidence is not less clear and substantial, and while in my handling of this subject I shall adduce the support of an authority of the highest weight, that of the late Mr. Godwin-Austen.[2] The preceding epoch was one of elevation of the land, and of this the evidence is of two distinct kinds, going to show that the uplift was sufficient to lay dry the bed of the English Channel and bordering sea round the coasts of England and France, producing that remarkable now submerged feature known as the "Continental Shelf".

This brings me to refer to the Continental Platform. This physical feature consists of a gently shelving plain extending from the existing coasts, and stretching out into the Atlantic for a variable distance, 50 miles or more, and at its outer margin breaking off in a steep, sometimes precipitous, descent into the abyssal depth of the ocean. Its margin generally coincides with the isobathic contour of about 100 fathoms opposite the mouth of the English Channel, and it is traversed not only by channels of rivers continuous with those now entering the Atlantic along the western coast, but also by a submerged river valley which is entirely under water, which I have

[1] In Lancashire these Interglacial sand-beds with marine shells are overlain by an Upper Boulder-clay of marine origin, as shown by the shells it contains (*Turritella*, *Fusus*, *Purpura*), and a fine section showing this superposition of the Upper Boulder-clay on the Interglacial sands is laid open on the banks of the Ribble above Preston. I have given an account of these Pleistocene deposits in *Contributions to the Physical History of the British Isles*, 1882, chap. xiii. The sands and gravel are probably the representatives of the "Middle Glacial beds" of Messrs. Wood and Harmer, of Norfolk.

[2] In his communication to the Geological Society entitled "Valley of the English Channel": Q.J.G.S., vol. vi, 1850.

ventured to name "the English Channel River". It will be necessary for me to return to this subject later on. (See Map, Plate VI.)

The margin of the Continental Platform was traced by the late Mr. Hudleston,[1] and described before the British Association at Bristol, but without the intersecting channels; and also by Dr. Nansen, Professor Spencer, and myself,[2] and is now recognized as a former coastline at a time when the sea-bed was about 100 fathoms above its present level. On the platform thus circumscribed the whole of the British Isles and Western Europe are planted. It is needless to say that the physical features there determined have been based on the isobathic contours which may be traced by means of the soundings recorded on the Admiralty Charts.[3]

Littoral Shells of the Channel Bed.—The statements of Godwin-Austen regarding the shells dredged from the bed of the Channel at depths of 60 or 70 fathoms (360–420 feet) is confirmation of the view that the Channel was contiguous with dry land at a former period. He says: "The great proportion of these shelly materials (forming the floor of the Channel) has come from a contiguous higher zone; but mixed with these, and in considerable abundance, are the pounded fragments of the commonest littoral species. Thus the *Haliotis tuberculata*, which lives about Brittany and the Channel coast just below ordinary low water, has its fragments carried out 50 miles from the nearest coast, and with it abundantly *Patella vulgata*", and at the Little Sole Bank in a depth of water of 60 or 70 fathoms *Turbo littoreus* is found near the edge of the Continental Platform, where the water descends to great depths; and the conclusion which he draws is that the whole of the Channel valley had at some former period a higher level than at present.[4]

Again, in the paper read before the Society by the same author "On the Pleistocene Period", he states that in order to account for certain phenomena of this region it is necessary to infer an elevation of great amount, such as would place the whole of the higher portions of this country in regions of excessive cold.[5]

The English Channel River.—I now come to state the evidence for the existence of the submerged river valley to which I have already alluded, the presence of which on the Admiralty Chart is conclusive of former land conditions over this region. So clear is this submerged channel, that the officers engaged on the soundings have traced its course for a distance of 60 miles and named it "The Hurd Deep", after its discoverer. Its total length is about 300 miles from its source near the Straits of Dover to its outlet at the margin of the Continental Platform, where it has worn a deep channel into the ocean. Its channel appears to have been swept free of sediment where the English Channel is narrow between Cape de la Hague and Portland Bill, and the tidal current is exceedingly strong; but when

[1] British Association Report, Bristol. [2] Ibid.

[3] The margin of the platform nearly coincides with the meridian 9° 5′, W., and its position at the edge of the steep descent has been recorded by Godwin-Austen from soundings by himself (1850). "Valley of the English Channel": Q.J.G.S., vol. vi, p. 76.

[4] Ibid., p. 85. [5] Ibid., vol. vii, p. 130.

the width increases to nearly double the distance, and the current has proportionately become slower, the sediment seems to have silted up the channel so as to be, for some distance, indeterminable.

Enough has probably now been advanced to show that land conditions prevailed during a period included within the time-limits of the great Post-Pliocene or Glacial Uplift. The conditions we have been considering were only those of a stage in the still greater uplift, and subsequent descent of the land; and as the submerged river valleys of Western Europe are traceable to a depth of 6,000 feet below the present sea-level, where they open out on the Atlantic floor, it is evident that the ocean-bed and the adjoining lands were uplifted into those altitudes of 'excessive cold' postulated by Godwin-Austen, who with that prescience for which he was so remarkable had almost advanced a prophetic solution of the hitherto mysterious problem of the cause of the 'Great Ice Age', a solution which for my part I am prepared to maintain as one sufficient in itself, and in harmony with the physical conditions revealed by the deep-sea soundings.[1]

Part V: Conclusion.

I have endeavoured to add a chapter to what has been so ably written by previous authors on the geological history of this interesting island and its neighbouring lands, based on individual strata of gravel, apparently of little interest in comparison with the fine assemblage of Tertiary beds on which they repose, but, as I have endeavoured to show, having a not unimportant place in the geological and prehistoric record.

It now only remains to recapitulate the physical changes which in this district at least took place at the close of the Tertiary period down to the present time. We begin with uprise of the Tertiary and Cretaceous beds.

1. Earliest stage. Axis of the Isle of Wight. Stratigraphical upthrust of the Cretaceo-Tertiary beds by lateral pressure; formation of an E.-W. axis, followed by denudation of the strata and long lapse of time.
2. Regional uplift and formation of the Continental Platform, uniting Europe and the British Isles—English Channel River Valley.
3. Submergence to extent of 400 feet and over in South of England, increasing northwards and reaching from 1,200 to 1,300 feet in Wales and Ireland. Beds of gravel and sand in Surrey, Norfolk, the Midlands, Lancashire, and Wales.
4. Re-elevation into present condition of land and sea; formation of low terraces, with works of art and extinct animals. The latest elevation of low-level gravels being probably within the period of the Roman occupation.

[1] The author has in preparation a monograph on the "Sub-oceanic Physiography" of the Atlantic Ocean, showing by charts the position of the submerged terraces and river-channels which descend to depths of 6,000 or 7,000 feet, and are continuous with the existing rivers of Europe.

III.—Description of a Diamantiferous Gem-Gravel from the West Coast of Africa.

By F. H. Hatch, Ph.D., M.Inst. C.E., Vice-President of the Institution of Mining and Metallurgy.

The material described in this paper was handed to me by the Liberian Development Company (to which I acted for some time as technical adviser) and was obtained in the course of prospecting operations prosecuted by that Company at Banja Ta (Montserrado) on the Jiblong and Bor Rivers (tributaries of the Junk River), some thirty miles inland from Monrovia, the chief port of the State of Liberia.

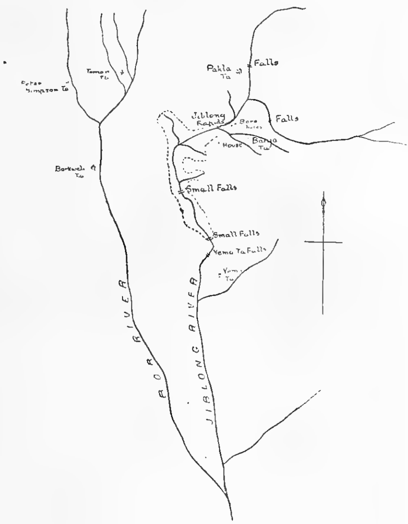
Diamonds and gold were discovered in the alluvial gravels of these rivers by the late Mr. George G. Dixon, and the concentrates submitted to me for examination were brought to this country by Mr. Dixon at the end of 1910. Mr. Dixon returned to Liberia soon after I had seen him; but unhappily he succumbed to an attack of malarial fever early in 1911. The subsequent prospecting work was carried on under the direction of his assistant, Mr. S. M. Owen, who at the end of the working season of 1911 brought me a series of rock-specimens and cores from boreholes (most of which were put down near the rapids to be referred to presently), so that I am enabled also to give a brief description of the solid geology of the district.

The bed-rock on which the alluvial gravels rest consists of an ancient floor of crystalline rocks, comprising: quartz-felspar-biotite gneiss with accessory sphene and zircon; garnet-hypersthene-biotite gneiss, composed of abundant red garnet, strongly pleochroic hypersthene, brown mica, chlorite, together with granulitic quartz and a small quantity of striated felspar; and coarsely foliated hornblende schist, consisting of green hornblende, plagioclase, quartz and sphene. All these rocks present a well-marked banding, the general strike of the country as reported by Mr. Dixon being N.E. and S.W., with a dip to the S.E.,[1] and give the impression of belonging to an ancient sedimentary series which has been profoundly modified by metamorphism. Associated with them are dark-coloured basic intrusions which, as the microscope shows, consist of water-clear plagioclase, green hornblende and hypersthene with marked granulitic structure, constituting a rock of the pyroxene-granulite or norite type.

Except in the bed of the River Jiblong itself, where comparatively unweathered specimens of the rocks can be obtained from the bars that stem the flow of the water and thus give rise to falls and rapids, all the rocks are entirely replaced at the surface by red and yellow lateritic or whitish kaolinized products; but excellent material for microscopic examination was obtained in the shape of cores from the diamond drill which was freely used in the prospecting operations of the Company. The object of the prospecting was two-fold: (1) to ascertain the quantity and value of the diamantiferous gravel, and (2) to find if possible the source from which the diamonds came. It was with the latter object that the borings were made. To ascertain the extent and value of the diamantiferous gravel the following method of prospecting was adopted: First, sites for pits were marked out at

[1] Cf. J. Parkinson, "A Note on the Petrology and Physiography of Western Liberia": Quart. Journ. Geol. Soc., vol. liv, 1908, p. 313.

fixed intervals across the alluvial flats. The pits were then sunk, the overburden being discarded and the gravel washed. Concentration was effected by the ordinary methods of sluicing and sizing by sieving, the final product being obtained by hand-jigging. From this the diamonds were recovered by hand-picking. The following is the number and weight of diamonds found during the prospecting operations carried on during 1910 and during the first part of 1911: 247 stones, weighing $85\frac{40}{64}$ carats, in the Jiblong River, and 22 stones, weighing $4\frac{13}{64}$ carats, on the Bor River. The largest stone found weighed $4\frac{40}{64}$ carats. Diamonds were found in the Jiblong River and in its alluvial flats for a distance measured along the river of a little over a mile and a half. This stretch of the river is situated between the rapids below the Pakla Ta Falls and the small falls above the Yema Ta Falls (see Map). This stretch of country is comparatively flat, but measured [1] from the top of the Pakla Ta Falls to the bottom of the Yema Ta Falls the river has a total drop of about 100 feet.



Sketch-map of the Jiblong and Bor Rivers from a survey by S. M. Owen. Scale, 1 inch = 1 mile. The area in which diamonds have been found is indicated by a pecked line.

The average width of the flats in which the diamonds were found is 238 feet. The average thickness of the diamantiferous gravel between the overburden and the bed-rock was found to be 6 feet. Diamonds were also found in the Bor River which joins the Jiblong at Careysburg, three miles below the Yema Ta Falls, but no extensive deposit exists in this river valley.

The samples of the 'deposit' or concentrate from which the diamonds had been picked, consisted of a mixture of heavy minerals, together with quartz, limonite, and rock fragments. The quartz was

[1] According to a survey of Mr. S. M. Owen, A.R.S.M.

easily removed by a preliminary treatment with bromoform of density 2·9. The residue still contained limonite, some rock fragments, and particles of tourmaline, the bulk of which was removed by treatment with a borotungstate of cadmium solution, having a density of 3·4. A mixture of heavy minerals was then obtained which could only be separated by hand-picking with the aid of a lens. This, although a tedious task, was found to be quite practicable; and a number of parcels of distinct minerals were thus obtained, the final determination of which was arrived at by taking the density, testing the hardness and streak, and, where practicable, measuring the crystal angles. In those cases where there was sufficient material, chemical tests were also made, both by dry and wet methods.

For permission to carry out this work in the Chemical Laboratory of the Mineralogical Department of the University of Cambridge, I am indebted to Professor W. J. Lewis, F.R.S., and for assistance in making a few goniometric measurements of crystals, I have to thank Mr. Arthur Hutchinson, Demonstrator of Mineralogy in the University of Cambridge.

Of the samples examined the two principal ones were: A (No. 30) gravel from the upper flats, and B (No. 31) from the lower flats. Sample A consisted of kyanite, corundum, pyrites, ilmenite, zircon, rutile, epidote, and gold. Sample B consisted of garnet, kyanite, pyrites, chromite, magnetite, hæmatite, zircon, and diopside. It will be observed that in sample B from the lower flats the minerals garnet, chromite, magnetite, hæmatite, and diopside occur, which are not represented in the sample from the upper flats; and, moreover, the garnet occurs in great abundance. It is obvious, therefore, that some source of supply was available for the formation of the gravels of the lower flats which did not exist in the upper reaches of the river. In all probability this was the garnetiferous gneiss already mentioned. The presence of gold in sample A was accidental, as the gold from both samples had been previously removed. The particle of gold found in the sample was coated with amalgam, and its true character only became apparent after driving off the mercury by heat.

Diamond.—Of the uncut diamonds still in the London office of the Liberian Company and examined by me, some are perfect octahedral crystals showing the usual rounded edges and striated faces due to vicinal forms. Others are irregular cleavage fragments showing no original crystal faces, while others again are partially bounded by original faces and partly by octahedral cleavages. There are also flattened rudely triangular forms (macles) due to twinning on the spinel type. In many cases the faces are smooth with occasional triangular pittings; and, as a rule, there is no sign of true abrasion. Some of the faces of the crystals, however, have a roughened, fretted, or frosted surface which must, I think, be attributed to corrosion while the crystals were still in the igneous magma in which they were formed, rather than to any subsequent attrition. Many of the stones are pure white and flawless; but some have a yellow or brown tinge and there is the usual proportion of spotted material. The average value of the whole parcel has been appraised by A. E. North and Co., of Hatton Garden, at £2 11*s*. per carat.

Gold.—An examination of the gold obtained by washing and now in the London office of the Liberian Company shows that it has the usual characteristics of the noble metal when obtained from alluvial sources. It is fairly coarse, but not nuggety; the grains are of irregular shape and are usually somewhat flattened. The colour is a beautiful dark yellow, due to the low proportion of silver, the fineness on assay being 971 per 1,000 parts.

Kyanite.—This, the most abundant mineral in sample A and the second most abundant in sample B, occurs in pale-blue to pale yellowish-green glassy fragments bounded by faces of the prismatic zone with predominant macro-pinacoid (100) and perfect cleavages parallel to the same face. Many of the fragments are flecked with minute black inclusions apparently of an iron-ore (magnetite?). The density was determined as 3·72.

Corundum.—This mineral is abundant in sample A, but absent from sample B. It occurs as cleavage fragments with no signs of rounding; colour, a dull pink with imperfect translucency. The basal plane (111) shows the triangular reticulation of fine lines due to lamellar twinning on the rhombohedron (100). The density was determined as 4·0.

Garnet.—This, the most abundant mineral in sample B, is absent in sample A. It is a blood-red variety, probably that known as pyrope. The fragments are of an irregular shape, determined by the uneven fracture and imperfect cleavage characteristic of the mineral, and present no crystal faces. The density was determined as 3·98.

Rutile.—This mineral is fairly abundant in sample A, but was not found in sample B. The fragments present dominant faces of the prism zone with vertical striation. The metallic-adamantine lustre is a predominant characteristic. Fractured surfaces show a reddish colour and there is a slight translucency at the edges. The density was determined as between 4·1 and 4·4.

Zircon.—A few crystals of zircon were found in both samples. One or two are almost perfect crystals—the prism (110) terminated by the pyramid (111). Colour, dark brown; lustre, vitreous. The density was determined as 4·75. Some colourless crystal fragments in sample B possessing strong double refraction and a high index of refraction (greater than that of methylene iodide) appear to be a special variety of this mineral. A goniometric measurement of the angle between two adjacent faces gave 48°, which corresponds closely to the angle (111) (110) = 47° 50′.

Chromite.—This mineral is fairly abundant in sample B, in rather small iron-black grains with sub-metallic lustre, giving a blackish-brown streak. As a rule the grains are irregular with conchoidal fracture or rounded, but one showed the spinel type of twinning. Fusion with borax gave the characteristic chromium reaction. The density was determined as 4·92.

Ilmenite.—This mineral occurs in sample A in tabular iron-black fragments with brilliant metallic lustre. Goniometric measurement gave the following results:—

$$111 : 100 = 57^\circ\ 59'$$
$$111 : 31\bar{1} = 61^\circ\ 44'$$

which agree sufficiently closely with those of ilmenite.

The presence of titanium was also proved by the yellow colour obtained with peroxide of hydrogen in the sulphuric acid solution, and by the blue colour obtained with tin in the hydrochloric acid solution. The density was determined as 4·72.

Hæmatite.—A few rounded reddish-black grains of this mineral were found in sample B. They are characterized by a brilliant metallic lustre on the surface, but are partially converted to limonite in the interior. Hence the low density obtained, viz. 4·6. The streak was cherry-red.

Magnetite.—A few small black grains with metallic lustre are present in sample B. They are strongly attracted by a small bar magnet.

Iron Pyrites.—This mineral is present in both samples in irregular fragments, but is more abundant in sample A.

Diopside.—One grain of this mineral was found in sample B. It is green and translucent with a refractive index of 1·69. It shows the rectangular prismatic cleavage and two pinacoidal cleavages, one of which appears to be a diallagic parting. The density was found to be 3·4. It is probably the chrome-diopside variety.

Epidote.—One cleavage fragment of this mineral was found in sample A. It presents the characteristic pistachio-green colour and basal cleavage.

From this examination it is evident that the bulk of the particles making up the finer material of the gravels consists almost entirely of minerals that possess a high capacity for resisting weathering—such as quartz, the various oxides of iron, corundum, kyanite, garnet, tourmaline, zircon, and diamond. On the other hand, the readily decomposable minerals, such as members of the felspar, amphibole, and pyroxene groups, are, with one exception, conspicuous by their absence. The obvious conclusion to be drawn from this fact is that these alluvial gravels are not derived directly from the crystalline rocks, but come intermediately from the lateritic weathering products by which these are replaced at the surface and which would naturally fall an easy prey to river erosion.

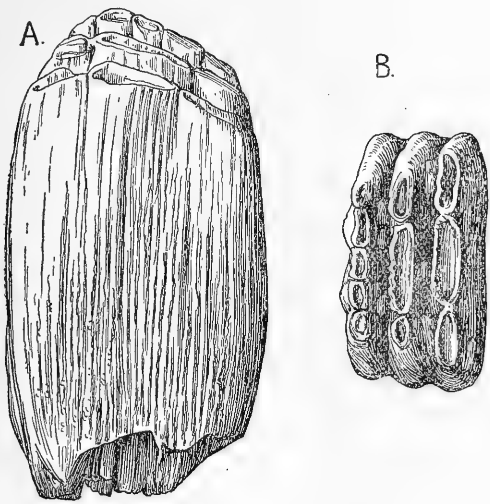
IV.—Note on the Molar Tooth of an Elephant from the Bed of the Nile, near Khartum.

By C. W. Andrews, D.Sc., F.R.S. (British Museum, Nat. Hist.).

In sinking the caissons for the construction of the bridge over the Blue Nile near Khartum, a considerable number of bones have been found, from time to time, in the alluvial beds, at depths of 60–68 feet below the level of low Nile. These specimens were obtained by Messrs. Hinckley, Stephen, and Le Bailly, and are now deposited in the collection of the Geological Survey of the Sudan at Khartum.

Most of the specimens have been sent to me for determination by Mr. G. W. Grabham, Geologist to the Sudan Government. The bones are all black or nearly black, very heavy, and highly mineralized through the infiltration of silica and iron, so that they present an appearance of much greater age than is usual in bones from post-Tertiary deposits. Mr. Grabham informs me that in this region these peculiar characters of preservation are very rapidly acquired, a friend of his, Mr. Bird, having found recent bones thrown by the natives into an old well, blackened and mineralized in a similar manner.

The specimens so far determined are remains of elephant, hippopotamus, a small giraffe, an antelope (? *Tragelaphus*), and a Siluroid fish. All these are, or were till comparatively recent times, living in the district. Lately, however, I have received from Mr. Grabham a specimen which seems to be of greater interest. It consists of three plates of the molar tooth of an elephant, which is certainly not the African elephant, the only species at present living on the continent.



Portion of a molar tooth of an elephant from Khartum. A, front view; B, crown view. ⅓ natˡ. size.

It is unfortunate that the specimen is so incomplete, but careful comparison with other elephant teeth renders it possible to arrive at fairly definite conclusions as to the relationships of this form.

The specimen (see Figure) consists of three plates probably from the hinder part of an upper molar. The plates are broad and much thicker than the bands of cement interposed between them, and their enamel is fairly thick and raised into a series of low vertical ridges, one on the middle of the anterior face being a little the most pronounced, but not sufficiently so to produce a marked prominence or loop on the outline of the surface of wear, such as is usual in *Elephas antiquus.* The posterior of the three plates is just coming into wear, the worn tips of the digitations forming five oval islands of enamel. The next plate has a wear-surface consisting of a larger median area, on either side of which is a smaller one. In the next also there are three distinct surfaces, but they are more nearly equal in size. The dimensions of this specimen are—

Greatest width of posterior plate	10·0 cm.
Greatest height of posterior plate (just in wear) .	20·0 ,,
Outside antero-posterior diameter of middle surface of wear of anterior plate	1·5 ,,
Thickness of enamel (average)	3–4 mm.

In the thickness of the plates and in the form of the wear-surfaces of the ridges, this tooth, so far as preserved, nearly resembles those of *E. meridionalis*, but, on the other hand, it differs widely from that species in the much greater height of the plates, which, in this respect, approach those of some specimens of *E. antiquus*, particularly some figured by Pohlig[1] under that name. As a rule, however, in that species, not only are the teeth not nearly so wide as in the present specimen, but the discs of wear usually show a marked mesial expansion, and there is a distinct loop in the enamel on the posterior side of the ridges at least.

Several other species of fossil elephants have been recorded from various parts of Africa. Of these *E. jolensis* and *E. atlanticus*, from Quaternary beds of Algeria, have been figured and described by Pomel.[2] Of these *E. jolensis* presents some likeness to our fossil, but its teeth are narrower, and it seems to approximate rather to *E. antiquus*. *E. atlanticus* approaches *E. africanus*, and the width of the plates and of the cement between them is greater than in the present form, in which, moreover, the tooth crown seems to have been higher.

Professor W. B. Scott[3] has described an elephant (*E. zulu*) from beds presumed to be of Pliocene age on the coast of Zululand. In this species the molars seem to have had lower and at the same time narrower crowns, though this latter character may, in part, be because the specimens described are from the lower jaw. The enamel is thicker and more crimped, and there is a well-marked enamel loop at least on the hinder side of the discs, which have a slight median expansion. *E. zulu*, in fact, seems to approach *E. antiquus* and *E. africanus* in the several points in which it differs from our specimen.

The tooth of the so-called *E. priscus*, figured by Falconer, differs in having a lower crown, discs more expanded in the middle, usually with distinct loops of enamel, and turning forward at their outer end.

Recently, Professor E. Haug[4] has given an account of a mammalian fauna from the River Omo, north of Lake Rudolf. Among the specimens are portions of the tusks and molars of an elephant, a milk molar of which is said to closely resemble one of *E. meridionalis*.

[1] "Dentition und Kraniologie des *Elephas antiquus*, Falc.": Nova Acta Leop. Carol. Deutsch. Akad. Naturforsch., Bd. liii, No. 5, pl. v, fig. 2, 1888.

[2] *Carte Géologique de l'Algérie* (Paléontologie—Monographies): Les Eléphants quaternaires. Alger, 1895.

[3] Third Rep. Geol. Surv. Natal and Zululand, 1907, p. 259, pl. xvii, fig. 6; pl. xviii.

[4] Haug, *Traité de Géologie*, vol. ii: Les périodes Géologiques, fasc. iii, p. 1727, pl. cxxx, 1911.

The collection also includes remains of a large *Dinotherium*, which seems to indicate that the beds are older than those containing the tooth now described. Possibly, however, the *Dinotherium* may not be from the same horizon as the elephant, in which case the latter may be the same species as our specimen.

A fragment of a molar, such as is here described, is not sufficient to found a new species on, but it shows that in the Sudan, as in other parts of Africa, the modern African elephant was preceded by a species more nearly approximating to forms found in other parts of the world. In this case the form preceding the modern species seems to have been practically an *E. meridionalis*, in which the molars had become much more hypsodont than in the European specimens.

It is greatly to be desired that, if possible, further collections be made from the deposits in which this interesting tooth was found.

V.—The Age of the Morte Slates.

By Dr. J. W. Evans, D.Sc., LL.B., F.G.S., and R. W. Pocock, B.Sc., F.G.S.

The discovery by Professor Reynolds in the Mendips strata representing the greater portion of the Silurian succession (Rep. Brit. Assoc. Portsmouth, 1911), showing no similarity to the slates of Mortehoe and the neighbourhood, has rendered it more difficult than ever to accept the attribution by Dr. Hicks of the latter rocks to the Silurian period (Q.J.G.S., vol. lii, p. 254, 1896); and now an important fact has come to light which appears to afford decisive evidence on this question.

Mr. J. G. Hamling, whose valuable contributions to our knowledge of the rocks of North Devon are well known, recently entrusted the authors, who are now working at the Morte Slates, with some exceptionally well-preserved specimens of fossils from Barricane Beach, on the Mortehoe side of Woolacombe, which were included in the exhibits of the Geologists' Association at the Shepherd's Bush Exhibition. Among these are examples of a *Spirifer*, evidently identical with *Sp. Hamlingi*, Hicks, from the same locality but in a better state of preservation than the type, judging by the figure in Dr. Hicks' paper; the authors have been unable to trace the original.

Mr. Hamling states that the new specimens, which are embedded in a matrix of yellowish grit, were found beside the path down to Barricane Beach. They were not actually in situ when discovered, but he has no doubt that they came from a small section close by, which was opened to obtain material to mend the path shortly before he visited the spot. The exact locality is three or four yards up the path from the beach on the left when ascending. He spent some time trying to find the grit in situ, but without success, and believes that it occurs in lenticles, and that the workmen dug out the whole of this particular lenticle, which was probably of no great length. The material employed on the path exactly matched that which remained in the newly excavated section, and nothing was brought from elsewhere. Dr. Hicks obtained his specimen of the *Spirifer* from the same place, but a little further down. It may be added that one of the fragments in which the fossils are embedded shows on one side a distinctly slaty facies, which presents a close resemblance to the normal Morte Slates of this area.

Spirifer Hamlingi must be classed with the 'aperturati' group of the genus and is undoubtedly a varietal form of *Sp. Verneuili*, Murch. (=*disjunctus*, Sow.). The fold and sinus are distinctly marked off from the side portions of each valve, and the sinus is narrower and deeper than it is in other varieties of the species. The number of the plications in the fold and sinus is about twelve. The valves are not distinctly winged, and the ratio of the breadth to the length is approximately four to three, the former measuring in the larger specimen a little more than 22 mm. and the latter nearly 17 mm. These figures may, however, be somewhat modified when the matrix is cleared from the specimen.

Closely similar but somewhat larger specimens in the British Museum (Natural History) are labelled "near Taunton". They are in a reddish-yellow grit, and were, Mr. Ussher believes, those described by the Rev. W. Downes (Trans. Devon. Assoc., 1881, pp. 293–7), which were found in New Red gravels at Bolham, and may have been derived from the Pilton Beds which outcrop to the northward. Gosselet figures a somewhat narrower form from the Schistes de Senzeilles (zone of *Rhynchonella Omaliusi*) at the base of the Famennian (Mém. Soc. Géol. Nord, vol. iv, pt. i, p. 30 and fig. 38, 1894), and a variety figured by G. and F. Sandberger under the name of *Sp. calcaratus* (Sow.) (Verstein. rhein. Schicht. Wiesbaden, 1850–6, pl. xxxi, figs. 10, 10*a*–10*c*) also presents many points of similarity. It may be added that no representatives of the species are found on the Continent lower than the passage beds between the Middle and Upper Devonian.

On one of the slabs there are also specimens of a *Rhynchonella*, which is probably identical with the form obtained by Hicks from the same locality and identified by him as *Rh. Lewisi*, Dav. They appear to resemble *Rh.* (*Camarotoechia*) *ferquensis*, Gosselet, from the Lower Frasnian of Belgium and the Boulonnais, and *Rh. letiensis*, Gosselet, from the Upper Famennian, two closely allied forms which were formerly included in *Rh. pleurodon*, Phil., into which the latter is believed by Gosselet to pass at the commencement of the Carboniferous period (Ann. Soc. Géol. Nord, vol. xiv, pp. 199 and 206, 1887).

There is therefore a prima facie case for placing the Morte Slates of Barricane Beach in the Upper Devonian and for regarding the apparent succession of the rocks on the coast of North Devon as the true one. At the same time it must be admitted that whenever the southern margin of the Morte Slates in North Devon has been examined there appears to be evidence of disturbance which renders it possible that there has been considerable dislocation of the strata along this line. This is, however, only what usually occurs at the junction of rocks which differ considerably in their physical characters in an area which has been subjected to powerful earth-movements, and does not imply that the faulting which may have taken place represents a large relative movement of the beds, and in the Marine Drive at Woolacombe there appears to be distinct evidence of a transition between the slates and the arenaceous Pickwell Down Beds, though the relations of the rocks are somewhat obscured by the surface-slipping that has taken place.

There is reason to believe that not only the Morte Slates but also a considerable portion of the Ilfracombe Beds belong to the Upper and not the Middle Devonian, with which they are usually classed. For *Stringocephalus Burtini*, Defr., which marks the highest horizon in the Middle Devonian, appears to occur near the base of the Ilfracombe Series in the Combe Martin Beds, and *Calceola sandalina*, Linné, which is the characteristic fossil of the Lower Middle Devonian, is wholly wanting, while a variety of *Spirifer Verneuili* is found in a quarry above Rillage Point, which should be comparatively low down in the Ilfracombe Beds, and *Rhynchonella cuboides*, Sow., which, like *Spirifer Verneuili*, is not found below the passage beds on the Continent, is also met with. Through the kindness of Professor McKenny Hughes, Dr. Evans had had an opportunity of seeing a well-preserved specimen of *Spirifer Verneuili* from Caple Pit, near Ilfracombe, which is believed to represent the same horizon.

The ascription of the Morte Slates to the Upper Devonian is not new. As early as 1889 they were placed by Mr. Ussher partly in the Middle and partly in the Upper Devonian (Rep. Brit. Assoc., 1889, p. 801), and in the same year Professor Kayser compared them with the Frasnian (Neu. Jahrb. für Min., etc., vol. i, p. 181, 1889).

The conclusions to which the authors have come with regard to the age of the slates of Barricane Beach do not necessarily apply to the rocks which have been included under the same name in Western Somerset. So far as their work has proceeded in that area it shows that the beds vary considerably in character, and are probably, as Dr. Hicks suggested (Q.J.G.S., vol. liii, p. 438, 1897), of very different ages; though whether they can be assigned to the horizons to which they were referred by him and Mr. Whidborne is a point on which the authors must for the present refrain from expressing an opinion.

It may be added that Mr. Ussher, who has done a considerable amount of work in West Somerset which has never been published, has volunteered to co-operate with them in that area.

VI.—On the Occurrence of Submerged Forests in certain Inland Lakes in Donegal.

By W. B. Wright, B.A., F.G.S., Geological Survey of Ireland.

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FOR many years past the Swedish geologists have been directing the attention of the scientific world to the curious phenomenon of the occurrence of submerged forests in certain of their inland lakes.[1] In our own country such evidences of change of level are a familiar sight along our sea-coasts, and, if we bear in mind the extreme

[1] Rutger Sernander, "Om förekomsten af subfossila stubbar på Svenska insjöars botten": Bot. Not., 1890. German translation in Bot. Centralbl., Cassel, Bd. xlv, 1891.
Arel Gavelin, "Studier öfver de postglaciala nivå- och klimatförändringarna

instability of the sea-level, their presence is little to be wondered at. In all bodies of water which have no outlet—and the sea is only the largest of these—the surface-level is determined by the balance between supply and evaporation, and oscillation is inevitable. In the case of freshwater lakes, however, the level is determined within small limits by the overflow, and the occurrence of tree stumps in the position of growth beneath their waters presents therefore a problem of considerable interest.

The Swedish cases already described may be classified under three heads—

(1) Trees which have become submerged owing to the transgression of the waters at one side of the lake as a consequence of the post-glacial tilting of the country.

(2) Trees which are submerged in lakes the outlet of which is through a marsh or peat moss. These cases admit of a simple explanation through choking up and raising of the outlet by the growth of vegetation.

(3) Cases where the outlet is over rock or drift, in which there is either no tilting, or the tilting is towards the outlet, or towards the opposite shore from that on which the submerged trees occur.

Several examples of class 3 have been discovered, and it is these which have a more special interest for us, for they are held by certain of the Swedish geologists to be capable of only one explanation, namely, that the lake during some period of its history was without outlet, and either entirely dried up or was considerably below its normal level.

Now in Ireland cases referable to class 2 are not uncommon,[1] but I am not aware of any case having, up to the present, been either described or observed which is without question referable to class 3.

In the summer of 1910, however, while engaged in geological mapping in the mountain and moorland district north-west of Pettigo, Co. Donegal, I came across several cases of this nature, having made a systematic search for evidence of change of level along the shores of all the lakes in the district. An area of 22 square miles of moorland was examined, and this was found to contain twenty-six small lakes. In seven of these submerged stumps of fir-trees can

på norra delen af det Småländska höglandet": Sveriges. Geol. Unders., ser. C, No. 204 (= Årsbok i, No. 1), 1907.

Rutger Sernander, "Hornborgasjöns nivåförändringar": Geol. Fören. i Stockholm Förh., Bd. xxx, p. 70, 1908.

—— "Hornborgasjöns nivåförändringar och våra högmossars bildningssätt": ibid., Bd. xxxi, 1909.

—— "Sjön Hedervikens vegetation och utveklings historia": Sv. Bot. Tidskr., Stockholm, Bd. iv, 1910.

L. von Post, "Skarbysjö-komplexet och dess dräneringsområdes postglaciala utvekling": Geol. Fören. i Stockholm Förh., Bd. xxxi, 1909.

Rutger Sernander, "Die schwedischen Torfmoore als Zeugen postglazialer Klimaschwankungen." *Die Veränderungen des Klimas*: Geol. Congress, Stockholm, 1911, p. 197.

Gunnar Andersson, "Swedish Climate in the Late Quaternary Period": ibid., p. 247.

[1] There is a submerged forest in Loch Fada in the Island of Colonsay, off the west coast of Scotland, to which attention was first called by Symington Grieve. The outlet of this lake is, however, through a peat moss; see W. B. Wright and E. B. Bailey, *Geology of Colonsay and Oronsay* (Mem. Geol. Surv. Great Britain, 1911).

be seen in the position of growth, but in three of the cases the outlet of the lake is through a peat-bog, so that no conclusion regarding the failure of the outflow during the growth of the trees could be based on them. In the remaining four (Loughs Bannus, Avehy, Drumgun, and Afurnagh) the outlet is over rock or boulder-clay, but the last-named is open to exception, as it is extensively margined by peat, through which it may possibly at one time have had a lower drainage.

Lough Bannus is situated on the Donegal Road, 2 miles W.S.W. of Pettigo. Its surroundings are shown in Fig. 1. It lies among drumlins, and has its outflow to the east over boulder-clay, the stream, however, soon entering a little rocky valley without any great fall. The outlet has been lowered by artificial cutting to the extent of about two feet, and there is an abandoned shore-line about the same

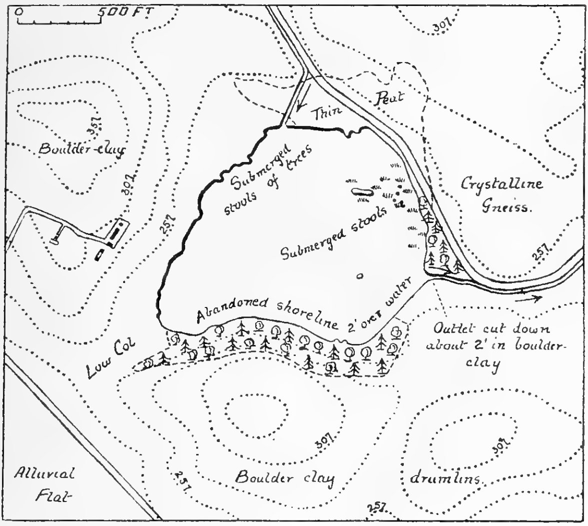

FIG. 1. Map of Bannus Lough, showing the position of the submerged tree stumps and the contours of the surrounding ground.

height above the water surface round the south side of the lake. It is clear, therefore, that in its natural state the lake was some two feet or so higher than at present. Tree stumps, submerged even at the present day, have been observed in two places, one on the northern shore and one on the eastern. The latter appear to be in the position of growth, the former are more doubtfully so.

Lough Avehy (Fig. 2) is on the Ballintra Road, $4\frac{1}{2}$ miles west of Pettigo. Its southern and western shores are formed of boulder-clay, and its northern and eastern of crystalline schists. It has cut fairly steep scarps, five or ten feet high, in the boulder-clay on the south side; but these are no longer being eroded, for the level of the lake has been lowered from two to three feet, apparently by artificial drainage, and there is an abandoned shore-line at about that height as in Lough Bannus. The outlet is to the east over rock debris and drift, the stream descending rapidly into a little rock gorge. The submerged tree stumps, which are obviously in the position of growth, occur in two places in a bay to the north-east of the lake. They are beneath the level of the water even at the present day.[1]

Drumgun Lough is a mile and a half due west of Pettigo. It is surrounded for the most part by boulder-clay, but rock appears on the shores in several places. The outlet is to the south between boulder-clay and rock. There is a fairly large peat moss bordering the lake at the east end, and a small one at the west end. Tree stumps are visible in the water on the northern shore, but it is possible

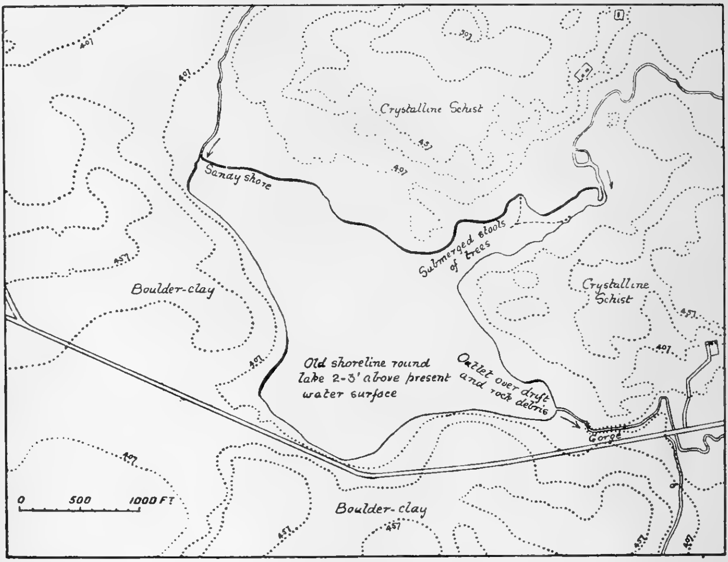

FIG. 2. Map of Lough Avehy, on the scale of 3 inches to a mile, showing the position of the submerged tree stumps and the contours of the surrounding ground.

that they are not in the position of growth. They are also to be seen on the eastern shore, where the lake at one spot is cutting away the bog. It is not clear in this position either that the submerged stools are in place. This is, however, a good locality for cutting a section in the peat, if it should ever be desired to determine the relations more exactly.

Lough Afurnagh lies on the moorland about two and a half miles W. 30 N. from Pettigo. It is surrounded on all sides by crystalline schists and peat mosses. It has its outlet to the west over a ledge of rock, but the shore for about a hundred yards to the north of the

[1] In the case of excavations ever being made with a view to further investigating the oscillations of level and the sequence of plant growth, I would suggest the sandy shore in the north-west bay of this lake as a suitable place.

outlet is formed of thick peat, which connects with the outflowing stream lower down, so that it is impossible to prove that the outlet has not shifted. This lake contains some of the most beautiful examples of submerged fir stools in the position of growth on both its northern and southern shores. It is in many places cutting away the peat at its margins, and exposing more stools both below and above the present water-level.

The remaining lakes which contain fir stools are Ultan, Aguse Mor, and Navarnan.

Lough Ultan lies on the crystalline schists about three miles north-west of Pettigo and north of the Donegal Road. There is a good deal of deep bog round it, and the outlet is through peat. At the south end of the lake there are some large submerged tree stumps in the position of growth, and also several in the middle of the western shore.

Lough Aguse Mor is near the Black Gap, to the south of the Donegal Road, 5 miles W.N.W. of Pettigo. It is surrounded almost entirely by bog, and has a sluggish outlet to the south through a level swamp. Fine examples of submerged tree-roots in the position of growth occur all round its northern and eastern shores, there being one magnificent fir stool, 9 feet in diameter, on the eastern shore.

Lough Navarnan is about a mile north-west of Drumgun Lough. The outlet is to the south through a peat moss. It has evidently been lowered by artificial cutting, for there is an abandoned shore-line round the lake about two feet or so above the highest floods of the present day. Submerged tree stumps can be seen at the north end of the lake.

Now although it is exceedingly probable that the submergence of the trees in all these lakes is due to the same cause, yet in any argument based on the facts here presented we are bound to put four of them aside, because it is impossible to prove that they had not lower outlets before the growth of the present peat-bogs. These four are Afurnagh, Ultan, Aguse Mor, and Navarnan. Drumgun is unconvincing for another reason—the submerged stumps in it are not demonstrably in the position of growth. There remain to us Loughs Bannus and Avehy. In these cases we are dealing with trees which grew below the present level of the outlet, and it is necessary in the next place to consider whether the outlet could not have been raised by tilting since the growth of the forest. One can suppose a special tilt for each lake, or a general tilting over a large area. Against the first supposition it is difficult to produce any argument, and it is certainly open to those who prefer such a hypothesis to adopt it as an explanation of this peculiar phenomenon. There is, however, a complete absence of any evidence of post-glacial folding or faulting in Ireland. Indeed, there is distinct evidence against it in the southern half of Ireland in the presence of a pre-glacial shore-line at a uniform level all round the coast. This shore-line has, however, not been traced into the north of Ireland, where the lakes under discussion are situated.

The hypothesis of a general warping or tilting of the country is much more plausible, because in the north and east of Ireland a deformation of this nature has been proved to have affected the

Campignien or Early Neolithic Beach. This proved warping, however, has a magnitude of only an inch or two in the mile, and is moreover in the wrong direction to serve as an explanation of the submergence on the shores of Loughs Bannus and Avehy. The smallest tilt that would cover the observed facts should amount to about 50 feet to the mile in the case of Bannus and 20 feet to the mile in the case of Avehy. If such an enormous movement as this has affected the district in general it ought to show itself on the sea-coast, unless indeed the shore-line of the forest period now lies so far beneath the sea that the tilting nowhere brings it above the surface. It is clear that an explanation based on tilting would strain our conceptions of post-glacial warping to the utmost.

There remains the explanation adopted by certain Swedish geologists to account for the same phenomenon in their own country. This is that the lakes during the growth of the forests had no overflow and sank beneath the level of their outlets. They ascribe this to the relatively dry climatic conditions which they suppose facilitated the growth of forest instead of bog. It is impossible to discuss here the merits of the climatic theory of the peat-bog succession, but it seems reasonable to assume that, if the Swedish cases are due to a period of dry climate, the Irish cases are to be explained in the same way.

Personally I do not feel at all certain that the mere existence of dense forests over the catchment area of these small lakes might not reduce the amount of water brought in by the tributary streams to such an extent as to lower the level of the lake, or even dry it up altogether except during exceptional floods. If, however, future advances in the study of the economy of forests should prove this idea to be untenable, there would seem to be but small chance of escape from the hypothesis of a very considerable change in the climatic conditions of the regions in which these submerged forests are found.

VII.—The Late Palæozoic Alkaline Igneous Rocks of the West of Scotland.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Assistant to the Professor of Geology, Glasgow University.

(*Concluded from the February Number, p. 80.*)

2. Essexite. (a) *Carskeoch type.*—A small boss of essexite, of rather basic type, pierces the agglomerate of the Carskeoch vent, near Patna, Ayrshire. Macroscopically it is light grey, compact, and fine-grained. In thin section it shows a plexus of fluxionally-arranged plagioclase laths of the composition $Ab_1\ An_1$, the interstices being filled with subhedral augite of a nearly colourless variety, and fresh olivine. Here and there minute angular interspaces are occupied with turbid isotropic matter, the form and arrangement of the particles of which suggest the former presence of nepheline. A few broad plates of pale augite and crystals of olivine interrupt the general trachytoid fabric. Ilmenite and biotite occur sparsely, and a little orthoclase may be detected on the margins of the plagioclases, extending irregularly into the interspaces. This rock has a distinct individuality,

and resembles neither the essexites of Lochend and Craigleith in the Lothians, nor the Crawfordjohn type described below. It is poor in alkali-felspars and felspathoids, is devoid of purple augite, and has a well-developed trachytoid fabric.

(b) *Crawfordjohn type.*—This type, which was first described by Teall, is named after the famous locality for curling stones in South Lanarkshire. The type-rock apparently comes from one of the long north-west–south-east dykes which are believed to be of Tertiary age. It is, however, so exactly identical with rocks from Lennoxtown and Patna, and so incongruous with the Tertiary suite that there seems no alternative than to regard the rock as belonging to the Late Palæozoic alkaline types. The Lennoxtown occurrence forms a massive irregular dyke intrusive in Calciferous Sandstone lavas on the southern slopes of the Campsie Hills; the Patna occurrence is a small boss intruding the agglomerate of the Late Palæozoic vent of Carclout Hill, and therefore establishes the age of this type. The latter occurrence is congruous with the presence of alkaline intrusions in other vents of the same district, and the Late Palæozoic age of the entire suite seems to be well established.

As the Crawfordjohn and Lennoxtown rocks have been previously described by Allport, Teall, and Bailey, only the new occurrence at Patna falls to be described here. In hand-specimens it is greyish, compact, fine-grained, carrying numerous lustrous black phenocrysts of augite. Microscopically it is composed of a plexus of broad laths of plagioclase (Ab_1 An_1), which are idiomorphic to abundant and often beautifully fresh nepheline. Limpid analcite occupies some of the interspaces and encloses the euhedral terminations of felspar laths. Titano-magnetite is aggregated into groups of euhedral crystals associated with flakes of biotite. In the above, as groundmass, numerous large phenocrysts of deep purple titanaugite and fresh olivine are set. The pyroxene moulds and encloses olivine, and occasionally also the terminations of the felspars. In size it ranges up to half an inch in diameter. The olivine rules much smaller, and should perhaps be associated descriptively with the groundmass. Apatite occurs in great abundance enclosed in nepheline and analcite. Nepheline occurs in the Lennoxtown and Crawfordjohn rocks, as described by Lacroix,[1] and Bailey.[2] It is sometimes, as in the Patna rock, so abundant as to make it a question whether the rock should not be described as a theralite. Mr. Bailey, however, has placed the Lennoxtown occurrence in the essexite family on account of its very close resemblance to Brogger's essexite from Brandberget, Christiania district.[2]

3. Kylite.—This well-individualized type occurs as a homogeneous and abundant set of sills and bosses in the Kyle district of Ayrshire, from whence it derives its name. It is an olivine-rich ultra-femic theralite or essexite. The chemical and mineralogical composition is quite distinctive; and as the rock is not a mere differentiation-facies of theralite or essexite, but forms numerous independent sills, it has been thought advisable to mark its individuality by giving it a new name.

[1] *Compte Rendu*, cxxx, 1900, p. 1273. [2] Bailey, loc. cit.

The massive sill of Benbeoch, near Dalmellington, is taken as the type - occurrence. Macroscopically the rock is compact, fresh, phanerocrystalline, and rather fine-grained. The dominant tint is grey or greenish grey, the latter when olivine is very abundant. In thin section the rock is composed of dominant olivine in fresh rounded crystals, and titanaugite forming large anhedral to subhedral plates and prisms much indented by the terminations of laths of labradorite. Many small rounded grains of olivine and some of ilmenite are poikilitically enclosed in the augite. Labradorite and subordinate nepheline form a kind of groundmass to the somewhat larger-sized ferro-magnesian constituents, which tend to form polysomatic groups, and thus take on a pseudo-porphyritic aspect. Some later felspars are zonal and range in composition from Ab_4 An_5 to Ab_5 An_3. Orthoclase may be detected on careful examination, bordering the lime - soda felspar. The nepheline is somewhat decomposed, but is recognized by the usual distinctive characters (p. 79). A little clear analcite was the last constituent to crystallize. The only other minerals seen are skeletal ilmenite associated with scraps of reddish biotite, and a little apatite. The general fabric is evenly granular. The rock has been analysed by Dr. Dittrich, of Heidelberg, with the result given in column I, Table IV below. Four other analyses are tabulated for comparison.

TABLE IV.

	I.	II.	III.	IV.	V.
SiO_2	44·18	42·87	48·57	40·32	44·42
TiO_2	1·30	—	1·48	2·66	1·63
Al_2O_3	10·67	10·93	10·51	9·46	13·33
Fe_2O_3	·97	3·44	2·19	4·75	9·14
FeO	10·03	10·14	9·45	7·48	6·35
MnO	—	trace	·16	·25	—
MgO	17·77	16·27	17·53	18·12	5·74
CaO	9·75	9·11	8·06	10·55	10·60
Na_2O	2·37	·92	1·59	2·62	5·60
K_2O	1·23	·13	·34	1·10	1·81
H_2O − } . . .	·97	·57	·10	·57	1·75
H_2O + } . . .		2·87	·37	1·25	
P_2O_5	·38	trace	·19	·68	·35
CO_2	trace	trace	none	—	—
S	—	—	—	·01	·18
NiO, Cr_2O_3, etc. .	—	—	·18	·27	—
	99·83	99·95	100·72	100·09	100·35
Sp. gr. .	3·05	—	3·065	3·148	—

I. Kylite, Benbeoch, Dalmellington.
II. Hornblende-picrite, Ty Croes, Anglesey. Bonney, Q.J.G.S., vol. xxxix, p. 256, 1883.
III. Ultra-femic olivine-basalt, lava-flow of 1852, Mauna Loa, Hawaii. Daly, *Journ. Geol.*, vol. xix, p. 296, 1911.
IV. Nepheline-basalt, Uvalde County, Texas. Cross, Bull. U.S. Geol. Surv., No. 168, 1900, p. 62.
V. Theralite, Flurhubl, Duppau, Bohemia. F. Bauer, T.M.P.M., vol. xxii, p. 281, 1903.

The Benbeoch analysis is remarkable for low alumina, very high magnesia, ferrous iron, and lime, combined with comparatively high alkalies. It does not correspond exactly with any known analysis. Its nearest affinity is the ultra-femic nepheline-basalt of Uvalde County, Texas. Analyses II and III correspond fairly well with it in all except the alkalies, which are much lower than in the Benbeoch rock. This is accounted for by the absence of felspathoids in these rocks. Compared with a typical theralite the kylite analysis shows a considerable diminution in alumina and alkalies, but contains almost three times as much magnesia for about the same silica percentage. Kylite therefore appears to fall into place as the plutonic equivalent of an ultra-femic nepheline-basalt.

The quantitative mineral composition, as estimated by the Rosiwal method, is given in column I, Table V below, together with mineral analyses of the principal variations of the rock. The labradorite in each case includes a little orthoclase, perhaps 2 or 3 per cent.

TABLE V.

	I.	II.	III.	IV.
Labradorite . . .	26·8	33·1	32·3	17·0
Nepheline . . .	3·8	2·3	6·1	—
Analcite . . .	1·8	·6	1·4	4·7 [1]
Titanaugite . .	25·1	27·6	25·9	19·7
Olivine . . .	37·8	29·5	27·9	55·4
Ilmenite . . .	2·1	4·4	4·3	2·5
Biotite . . .	2·0	1·8	1·4	—
Apatite . . .	·6	·7	·7	·7

I. Kylite, Benbeoch, the dominant type, analysed by Dr. Dittrich.
II. Kylite, a less femic facies, Benbraniachan.
III. Kylite, a less femic facies, Craigmark.
IV. Kylite-picrite, an ultra-basic facies, Chalmerston Hill, Benbeoch.

It will be noted that all these rocks are dofemic, to use a convenient term. Although the type represented by I forms at least three-quarters of the mass of Benbeoch, some distinct varieties, represented by II, III, and IV, must be recorded. II and III are satellitic outliers of the upper part of the Benbeoch sill, and are notably richer in the felspathic constituents and poorer in olivine. IV, on the other hand, forms an ultra-basic stratum at or a little below the centre of the sill. This facies consists principally of large euhedral to subhedral crystals of partially serpentinized olivine, forming 50–60 per cent of the rock. Large plates of titanaugite and fresh plagioclase form the major part of the remainder. Both minerals poikilitically enclose numerous small rounded olivines. The augite and felspar are idiomorphic towards a turbid base, partly identifiable as analcite and partly indeterminate, which encloses flakes of biotite and large cross-fractured crystals of apatite. The felspar plates show in unusual perfection the radiating fissures springing from enclosed olivine.

[1] This includes a little unidentified turbid matter.

This *couche* of ultra-basic rock in the centre of the Benbeoch sill appears to be susceptible of precisely the same explanation as that adopted for the similar phenomena of the Lugar complex (p. 76); and also for an olivinic ledge in the Palisade quartz-diabase sill of New Jersey.[1]

C. *Rocks without conspicuous Analcite or Nepheline.*

Associated with the more alkaline types described above are a great number of less alkaline rocks, which, however, betray their affinities by the abundance of purple augite and the occasional presence of an interstitial wedge of clear analcite. Some of them accompany the analcite-syenites apparently as differentiation-facies. Others form small masses intrusive in the highest horizons in the West of Scotland—the 'Permian' red sandstones and lavas of the Mauchline district. While rather variable in their characters it does not seem possible to divide them into well-characterized groups. The following description applies particularly to the sill in the Trabboch Burn, near Stair, Ayrshire, a fresh and typical example of these rocks which may serve as a type of the whole suite. It contains a few veins and irregular patches of analcite-syenite.

Megascopically the Trabboch Burn rock is greyish in colour, medium and even-grained, consisting essentially of grey felspar and black pyroxene in approximately equal proportions. In thin section the rock consists of a coarse-grained aggregate of broad laths of zonal plagioclase in subophitic relations with large subhedral to anhedral plates of purple titanaugite. Fresh olivine occurs in some quantity, and also ilmenite, the large skeletal aggregates of which are intergrown poikilitically with the pyroxene. It is associated, as usual in these rocks, with a few scraps of red biotite. A soda-bearing orthoclase may occur in some quantity, generally with analcite. The latter fills up interspaces and encloses the idiomorphic terminations of felspars, grains of augite, and needles of apatite. The proportions of orthoclase and analcite are very variable, and in some sections they are absent. The plagioclase is highly zonal, ranging in composition from $Ab_1 An_1$ to $Ab_1 An_3$, and has often suffered partial analcitization.

All the other rocks falling under this group have the same general aspect as the above. There is, however, considerable variation in the proportions of certain constituents. Analcite and orthoclase frequently fail, olivine often becomes an abundant constituent, whilst many of the rocks show a perfect ophitic structure.

These rocks are ophitic dolerites, which, whilst not conspicuously alkaline, show considerable affinity with the alkaline series. This may be appropriately recognized by terming them *alkali-dolerites*. Those varieties which contain analcite and soda-orthoclase belong to the essexite family, and their doleritic aspect may be recognized by the designation *essexite-dolerite*. They closely resemble the 'crinanites' of Argyllshire. (Mem. Geol. Surv., *Geology of Colonsay*, 1911.)

[1] J. V. Lewis, *Annual Report of State Geologist for 1907:* Geol. Surv. of New Jersey, 1908, p. 129.

The alkali-dolerites and essexite-dolerites are abundantly developed in the Dalmellington district. The chief localities are Muck Burn, Dalnean Hill, Dalcainnie Hill, Grimmet Glen, Whitehill (Patna), Polnessan Burn, Rankinston, Dunaskin Glen, and Ashbeugh Glen. In the district of which Tarbolton is the centre, the chief localities are Auchincruive, Helenton, Howford Bridge, Dippol Burn, Trabboch Burn, Stair, Failford, Auchinweet, and Barskimming.

The analcite-syenite differentiate is only found in the Mauchline–Tarbolton district; it has not been recognized in the Dalmellington area. In the latter, however, the alkali-dolerites sometimes contain pink acid veins, notably at Muck Burn, Dalmellington, and the Coyle Water, Rankinston. At the latter locality the veins consist of a medium-grained plexus of zonal plagioclase margined by orthoclase, associated with an approximately equal quantity of moiré and perthitic orthoclase in broad anhedral plates. A little granular pyroxene and skeletal ilmenite is enclosed in the felspars, also some biotite and chlorite; but the proportion of femic minerals is very small. This rock has affinities with the monzonites.

The Muck Burn variety is much finer in grain, and attains a vein-width of 5 inches. It consists of a fine-grained aggregate of well-shaped laths of orthoclase and acid oligoclase, the latter slightly predominating. The interstices are filled with quartz and crypto-crystalline matter. The only other constituent is a little leucoxene. The structure is typically orthophyric, and the rock might be termed a monzonitic orthophyre. If the orthoclase is soda-bearing, as is probably the case, the rock becomes a keratophyre.

D. *The Mauchline Lavas.*

These rocks occur in a narrow ring-shaped outcrop surrounding the 'Permian' red sandstones of the Mauchline–Tarbolton area. Their geological features have been described by Sir A. Geikie.[1] Their petrographical character is the subject of a brief note by Dr. Hatch in Sir A. Geikie's *Ancient Volcanoes*.[2] The picrite there described is probably one of the monchiquite or limburgite lavas. Mr. David Ferguson, who has devoted much attention to this district, estimates the thickness of the lavas at 280 feet. This thickness is made up by a number of thin flows intercalated with tuff and red sandstone. These intercalations increase in number and thickness towards the top of the lavas until they merge into the thick overlying sandstones. The lavas have been poured out from a series of small 'greenhill' vents situated mostly round the northern edge of the outcrop.[3] Numerous vents also occur round the margin of the high Carboniferous plateau to the north of Dalmellington, which was doubtless once covered by a cap of lavas. The vents contain lavaform material in blocks and apparently intrusive masses, which extend our knowledge of the petrography of this late series of Palæozoic lavas.

[1] GEOL. MAG., Vol. III, p. 243, 1866.

[2] *Ancient Volcanoes of Great Britain*, vol. ii, p. 57, 1897.

[3] Tyrrell, "The Geology of Mauchline," in *The Land of Burns*, by J. T. Gibb, of Mauchline, 1911.

Megascopically the lavas are very uniform in appearance. They are all compact, aphanitic, varying in colour from dark red to purplish, rarely grey or black. A very characteristic aspect is imparted by a universal red speckling due to the replacement of microporphyritic olivines by red iron-ores derived from the overlying sandstones. A red stain of diffused iron-oxide frequently gives the rocks an appearance of decomposition which is belied by the general freshness apparent in thin section. Porphyritic olivine is invariably present, augite rarely, but felspar never. The above characters easily distinguish these rocks from the earlier Carboniferous lavas, and have been found very useful in determining the age of some doubtful vents.

The following minerals have been found in thin section: olivine, almost invariably pseudomorphed by hæmatite, purple titanaugite, plagioclase ($Ab_1\,An_1$–$Ab_2\,An_3$), analcite, nepheline, and sparse iron-ores.

The lavas can be broadly divided into two divisions characterized by the presence or absence of felspar. The felspathic group is the most abundant, and includes femic types of olivine-basalt (cf. Hillhouse and Dalmeny types), analcite-basanite, and analcite-nepheline-basanite. The two latter are probably to be classed with the Kidlaw basalt of the Lothians.[1] In the Dalmellington district the vents contain blocks comparable to mugearite and Markle basalt (a non-porphyritic variety). These, however, are extremely rare. The felspar-free rocks include monchiquite, analcite- and nepheline-basalt, and limburgite, types which are also represented in the Lothians.[2]

The *olivine-basalts* consist of abundant micro-porphyritic olivines, pseudomorphed by hæmatite and serpentine, in a groundmass made up of granular augite and lathy plagioclase, the former usually predominating. The minute interstices are occasionally filled with analcite or with turbid material resulting from its decomposition. Transitional types connect these with the *analcite-basanites*, in which analcite occurs in sufficient quantity to rank as an essential constituent. In a rock from the Thornton vent, near Kilmaurs, the analcite occurs as a fresh pellucid, pervading base, enclosing a plexus of augite granules and plagioclase laths. Olivine and a little augite occur as phenocrysts. In another type from Sorn Hill, near Catrine, the texture is doleritic, and the analcite occupies large polygonal cavities, usually bounded by laths of felspar. It contains detached granules of deep-purple augite, and envelops projecting felspars which appear to have suffered corrosion. Olivine is abundant as phenocrysts with the usual hæmatite replacement; also augite in abundant large polysomatic aggregates of a much paler tint than the augite of the groundmass. This rock also contains nodules of closely packed granules of augite with a little felspar, but no nucleus of analcite. These are comparable with the ocelli found in similar rocks in the Lothians.[3]

A few of these rocks contain nepheline. It is always associated with analcite, and both minerals may occur in a perfectly fresh

[1] *Geology of East Lothian*, 1910, pp. 106, 111.
[2] Ibid., pp. 106–7.
[3] Ibid., p. 109.

condition in the same interspace. A typical example of these rocks occur in a vent exposed in the River Irvine, near Hurlford. This consists predominatingly of anhedral grains of purple augite with a little magnetite in an apparently continuous colourless groundmass, which, in polarized light, breaks up into laths of plagioclase, isotropic analcite, and low-polarizing nepheline. Both the latter occur in interstitial areas in which the nepheline occupies the margins, and projects with good crystal form into more or less decomposed analcite occupying the central space. The nepheline has the characters of 'nepheline x', described by Bailey, and is accompanied by a mineral of much the same appearance but lower refractive index, just as in the East Lothian occurrences.[1] These rocks may be termed *analcite-nepheline-basanite*. With increasing abundance of nepheline and a corresponding diminution of analcite and felspar, especially the latter, these rocks approach closely to the true *nepheline-basalts*. A rock from the Alton Burn, Tarbolton, is generally similar to the above, but is much richer in nepheline. The latter forms small plates poikilitically enclosing granules of augite. Small flakes of biotite occur abundantly in the groundmass, as well as apatite in large stumpy crystals, averaging one-tenth of an inch in diameter.

The true *monchiquite lavas* are well represented by a beautifully fresh rock from the burn near Stevenston, two-thirds of a mile north-east of Ochiltree. It consists of a crowded mass of small euhedral grains of titanaugite and sparse minute specks of magnetite embedded in a scanty base of analcite. Olivine is very abundant in small porphyritic crystals, partly fresh, partly hæmatized. A few small phenocrysts of augite also occur. The analcite tends to segregate into small rounded areas which have tangentially aligned prisms of augite around their margins. In the larger areas the mineral shows anomalous double refraction similar to that of leucite, and the cubic cleavage is well marked. Other slides from the same locality show large ocelli of augite with a nucleus of analcite carrying detached aggregates of augite grains and numerous minute crystals of ægirine. The groundmass of this rock is largely composed of fresh nepheline which forms small plates poikilitically enclosing the other constituents. We have, therefore, the rare type *nepheline-monchiquite*.

Limburgite, characterized by a glassy base, is known from one locality only, the hardened rim of the little vent at the Earthwork, Barnweill, near Tarbolton. This mode of occurrence suggests that the glass in the rock is due to the refusion of original analcite in a monchiquite lava. The glass is distinguished from analcite by the lack of cleavage, its dark-brown colour, and by the abundance of microlites of magnetite. The presence of glass in place of analcite is the only difference between this rock and the monchiquite described above.

Petrology.

It is not possible here fully to discuss the petrology of these rocks considered as a homogeneous suite or province possessing certain characters in common, and otherwise bearing indications of a common

[1] *Geology of East Lothian*, 1910, p. 110.

origin. The material is deficient especially as regards the chemical analyses which are so vital to such a discussion. Nevertheless it is possible to indicate broadly the salient characters of the suite.

Geological occurrence.—The rocks occur as sills, small lenticular intrusive masses, volcanic plugs, and as a series of lava-flows. No occurrence of true abyssal habit is known. The intrusions are on a comparatively small scale, and range from occurrences, the outcrops of which cover only a few hundred square yards, to some, such as those of Craigie and Dundonald, which cover several square miles, and have a thickness of over 100 feet. Many are lenticular in form; others, however, are stratiform, and have a horizontal extension which is very great as compared with their thickness. This form frequently characterizes the sills rich in analcite, the original magma of which must have possessed unusual liquidity. A concomitant effect is a marked differentiation, which is usually best developed in sills, such as that of Lugar, having a wide horizontal extension.

The volcanic plugs may consist merely of lavaform material; but kylite, teschenite, and other rocks have also been found with this mode of occurrence. At Carskeoch Hill, near Patna, the agglomerate is pierced by a very heterogeneous complex (p. 120). The lavas occur in thin impersistent flows. The 280 feet of thickness estimated by Mr. Ferguson includes a large number of intercalations of tuff and sandstone. The lavas have been poured out from several 'greenhill' vents, characterized by their bright-green vegetation and sharply conical form. A thin skin of lava is occasionally found adhering to the walls of an agglomerate vent.

The sieve-like perforation of the sedimentary rocks by these vents is reminiscent of the Mid-Miocene vulcanicity of the Suabian Alb, as remarked by Daly. It is noteworthy that Daly has adduced the Ayrshire and Fifeshire districts as examples of secondary vulcanism, due to the opening of vents above satellitic intrusions. He remarks: "The steady association of tuff-neck and sill in the Scottish shires scarcely looks accidental."[1]

A remarkable absence of dykes belonging to this suite is to be noted. The only one known to the writer is a thick dyke-like mass of theralite (Bellow type) crossing the Lugar Water just below the Lugar sill. This is probably connected underground with the theralite of the Lugar sill. The Crawfordjohn dyke is a doubtful example and requires further investigation.

Chemical and Mineralogical Characters.—The chemical characters of the suite cannot as yet be adequately discussed. The chief points to be noted are that the magmas generally are poor in silica and rich in alkalies, especially soda, which is always in excess of potash.

The characteristic mineral of the suite is analcite. It occurs in almost every member, sometimes in large quantity, and in such relations to the other constituents as to establish indubitably its primary character. Indeed, this suite should go far to demonstrate the existence of an analcite series of igneous rocks parallel to those

[1] R. A. Daly, "Nature of Volcanic Action": Proc. Amer. Acad. Arts and Sciences, vol. xlvii, pp. 117–18, 1911.

characterized respectively by nepheline and leucite. Nepheline is of comparatively rare occurrence. There is abundant evidence in these rocks that it can be formed along with primary analcite. The dominant felspar is labradorite of the composition $Ab_1 An_1$; orthoclase (a soda-bearing variety or sometimes anorthoclase) occurs in very subordinate quantity.

The characteristic ferro-magnesian mineral is a pleochroic augite of a peculiar deep purple-madder tint, which is generally held to indicate a high titanium and soda content. Olivine is very abundant, and a peculiar red barkevicitic hornblende is occasionally present in some quantity. Ægirine and arfvedsonite appear in the more acid rocks.

The suite has a general basic character. Amongst the intrusive rocks teschenite is by far the most abundant. It shows a decided tendency to pass over to ultra-basic modifications. Subacid rocks are very rare in comparison, and acid rocks are unknown. The lavas are basic, with a large number of types verging on the ultra-basic. The abundance of analcite indicates a parent-magma rich in water and alkalies. Other volatile substances were probably present which are not now represented among the constituents of the rocks. Apatite, however, is very abundant, and seems always to be associated with analcite or alkali-felspars. Hence it is probable that fluxes like fluorine or chlorine were present in the magma. Whatever fluxes were present, there is evidence to show that the magmas were usually very liquid; and to that liquidity must be ascribed the very complete differentiation seen in some of the intrusions. The liquidity in some cases was so great that differentiation was controlled more by simple gravity-stratification than by differences of temperature set up during intrusion. This remark applies to differentiation after intrusion; but assuming a single original magma-reservoir, there can be little doubt that some differentiation took place before intrusion, as is evidenced by the variety of rocks which constitute the suite.

Distribution and Age.

The areal distribution of the various types seems to have some significance. The teschenites are the most widely spread types. They are mostly intrusive in the Carboniferous Limestone Series in the areas remote from the central volcanic districts of Mauchline and Dalmellington. Thus they are common in North Ayrshire and in the Cumnock districts. The Glasgow teschenites are separated from the nearest Ayrshire occurrences by a wide interval, which is mainly occupied by a great mass of calciferous sandstone volcanics. If they are connected with the Ayrshire centre it is remarkable that no teschenites are to be found in the intervening area; unless it is that these rocks found the calciferous sandstone lavas difficult of penetration.

The principal teschenite-picrite masses are ranged on the margin of the Coal-measure area surrounding the central volcanic district, as at Cumnock, Lugar, and Patna. The kylites penetrate the Coal-measures in the zone immediately surrounding the 'Permian' lavas of Mauchline, and are mostly concentrated in the southern part of that zone. The essexite-dolerites and analcite-syenites intrude the lavas and overlying sandstones of the Mauchline area; and a zone of alkali-dolerite also occurs around the margin of the Coal-measure area of Dalmellington.

Despite minor irregularities, therefore, there appears to be a well-marked concentric distribution of the various types, in interrupted zones, with reference to the central volcanic area of Mauchline. Although the point needs confirmation by chemical analysis, it is probable that the Mauchline lavas are the effusive equivalent of the kylites rather than any other group.

This distribution provides a clue, not only to the relative ages of the main types, but also to the age of the suite considered as a whole. It is obviously distributed in relation to the lavas of the Mauchline tract, which overlie the Upper Red Sandstones of the Carboniferous, and are believed to be of Permian age. The widespread teschenites may represent the assumed parent-magma or one of the first differentiates from that magma. They were intruded into the lower levels of the adjacent strata, and were probably prior to the effusive phase. The highest horizon cut by them is the Coal-measures in the east of Glasgow. Here they are much faulted, and are without doubt of Late Carboniferous age.[1] The kylites, alkali-dolerites, and analcite-syenites may then be secondary or tertiary differentiates derived from subsidiary magma-basins intruded into the higher sedimentary levels at a later date, and accompanied by an effusive phase which gave rise to the Mauchline lavas.

The suite may therefore be assigned with much probability to the close of the Carboniferous period. Possibly the later members belong to the succeeding Permian. The Mauchline lavas have been assigned to the Permian by Sir A. Geikie.[2] Some doubt, however, attaches to the correlation, and there is some probability for the view that the red sandstones which overlie the Mauchline lavas are merely the upper part of the barren red sandstones of the Coal-measures, the two portions being separated by a volcanic episode.[3]

An allied suite of alkaline rocks has recently been described from the Lothians. These are intruded into the sediments above the Calciferous Sandstone lavas, and are thus clearly subsequent to this effusive period. The great majority intrude the Carboniferous Limestone Series. These later basic analcite-bearing rocks are said to bear a great resemblance to some of the lavas of Burntisland and Bathgate, belonging to the Carboniferous Limestone Series.[4]

It still seems questionable, however, whether some of the alkaline intrusions of the Lothians and Fife may not be linked on ultimately with a later volcanic episode than that of the Calciferous Sandstone or the Carboniferous Limestone. The famous 'Permian' volcanic vents of the Fifeshire coast, so well described by Sir A. Geikie,[5] are doubtless contemporaneous with the volcanic episode of the Mauchline district. The lavaform products have a striking similarity, although so far as is yet known, nepheline-bearing rocks have not been met with in the

[1] Mem. Geol. Surv., *The Geology of the Glasgow District*, 1911, p. 112.
[2] *Ancient Volcanoes of Great Britain*, vol. ii, p. 55, 1897.
[3] Tyrrell, Trans. Glasgow Geol. Soc., vol. xiii, pt. iii, p. 314, 1909.
[4] Mem. Geol. Surv., *Geology of East Lothian*, 1910, p. 104.
[5] Ibid., *Geology of East Fife*, 1902.

Fifeshire vents. It may well be, however, that on a thorough examination of material in these vents, a fuller correspondence may be established, in both intrusive and extrusive types, with the Ayrshire district. It is possible, therefore, that just as the intrusive alkaline rocks of the west are related to the Mauchline volcanic episode, so the similar rocks of Fife and the Lothians may be related to the latest ('Permian') volcanic episode of that district.

The fact emerges that the distinctively alkaline phase, at least as regards the intrusive types, began earlier in the Lothians than in the West of Scotland. In the former area the alkaline intrusions date from the Carboniferous Limestone; in the latter from the Coal-measures. The western suite as a whole was a little later than the eastern, and links itself definitely with a late Carboniferous or Permian volcanic episode; whilst the eastern suite appears to bridge the gap between the Calciferous Sandstone lavas and the 'Permian' volcanic episode of Fife.

Considered in relation to the homogeneous mass of alkaline types erupted during the Carboniferous period in the Midland Valley of Scotland, the western suite falls into place—recognizing the time element in petrographical provinces—as a sub-province and sub-period of the Carboniferous period-province of Central Scotland. Excluding the Glasgow teschenites, the boundaries of the sub-province are well defined to the north by the great mass of Calciferous Sandstone volcanics occupying North Ayrshire and Renfrewshire. These rocks, with Old Red Sandstone, also bound the area to the east. On the south and south-west the great Southern Upland marginal fault forms the natural boundary. To the west, however, the extension of the sub-province is indefinite. Some part may be faulted down beneath the Firth of Clyde. It extends at least as far as the Lady Isle, a teschenite mass in the Firth, 3 miles west of Troon; and may also include Arran and Bute. The Glasgow teschenites, as before stated, are remote from the Ayrshire district, and are possibly outlying members of the Lothians sub-province. It may be said that the western sub-province is approximately co-extensive with the county of Ayrshire, and that its time-boundaries are Coal-measures to Early Permian.

REVIEWS.

I.—Geological Survey Memoirs.

On the Mesozoic Rocks in some of the Coal Explorations in Kent. By G. W. Lamplugh, F.R.S., and F. L. Kitchin, M.A., Ph.D. 8vo; pp. vi, 212, with 5 plates and 5 text-illustrations. 1911. Price 3*s.* 6*d.*

It is well that the Geological Survey has been able to rescue from oblivion a most important series of data, stratigraphical and palæontological, that have been disclosed by some of the coal explorations in Kent, and in particular by those at Dover, Brabourne, Pluckley, and Penshurst. The researches, of which the results are embodied in this memoir, were indeed commenced so long ago as 1897, but the delay in publication can hardly be regretted, as fresh material was from time to time obtained, and the conclusions based upon an immense amount of careful detailed observation and study, are of the highest scientific interest and of considerable practical importance. Although permission to examine the material from the borings and shafts was given on the understanding that the investigations were not extended into the Coal-measures, nevertheless the information on the distribution and thicknesses of the various Mesozoic formations is all important in reference to the depth at which Palæozoic rocks are likely to be met with in areas hitherto unproved.

The memoir is divided into two parts of nearly equal length: the first, comprising "Stratigraphical Descriptions", is by Mr. Lamplugh; and the second, giving "The Palæontological Characters and Correlation of the Strata between the Gault Clay and the Trias", is by Dr. Kitchin. The four localities dealt with extend in almost a direct line from Penshurst, south-west of Tonbridge, to the Dover Coal-mine in Hougham parish, a distance of about forty-five miles. Records of these borings were published by Mr. Whitaker in his memoir on the *Water Supply of Kent* (1908), and a comparison of the information there given shows how much has been added with regard to the details and correlation of the strata.

At Dover, where the explorations were commenced in Chalk, less Folkestone Beds, more Sandgate Beds, and no Hythe Beds are recognized; and it is remarked by Mr. Lamplugh that there is "an intensified example of the condensation of sediments under strong current-action" in the case of the Folkestone Beds, as "although the Dover area remained beneath the sea during the accumulation of the Hythe Beds, the conditions were such that permanent sedimentation was not possible upon it". The attenuation of the Wealden Beds and the absence of Purbeck and Portland Beds are confirmed, and the unconformity is further marked by much erosion of the Kimeridge Clay. More Corallian is identified, the lower division, which is clayey and calcareous, being taken to include the *Cordatus* zone; and a less thickness is admitted of the Kellaways formation, which has yielded *Sigaloceras calloviense* at Tilmanstone. The Lower Oolites have been found capable of subdivision, and although Cornbrash is somewhat doubtfully distinguished strong support of the presence of the formation is afforded by fossils obtained from Tilmanstone north of Dover; the beds assigned to the Forest Marble also present some of the characters of that formation; the Great Oolite is clearly distinguished; and the Inferior Oolite may be represented by sands and calcareous grits which occur above the Upper Lias, but have yielded no fossils. The Upper Lias (*Serpentinus* zone), probably the Middle Lias (*Spinatus* zone), and the Lower Lias (*Capricornus* zone) are noted. Below come the Coal-measures.

At the Brabourne boring, commenced in Gault, another great series of formations has been proved, the records (with that of Dover), in the words of Mr. Lamplugh, being "unparalleled in Britain—or, so far as our knowledge goes, in any other part of the world—in the geological range and continuity of formations proved by them to exist in actual superposition in a single small area". The Folkestone

Beds, Sandgate Beds, possibly Hythe Beds, and Atherfield Clay are distinguished; but a less amount of Weald Clay than that given by Mr. Whitaker is now recorded. It is not surprising to those who have had to deal with well-borings, that difficulty is experienced in correlating the subdivisions of the Hastings Beds with those shown on the Geological Survey maps. Purbeck Beds are now introduced, and an illustration is given of a peculiar breccia similar to a bed exposed in the same formation at Hartwell and Haddenham in Buckinghamshire. The Portland Beds rest abruptly on the Kimeridge Clay, with indications of erosion, whereas at Pluckley and Penshurst these formations merge gradually one into the other. The Upper Corallian yields a band of "millet-seed iron-ore", as at Dover, but much reduced in thickness. The succession below is like that at Dover, with more Oxford Clay, subdivided into the *Mariæ*, *Renggeri*, and *Ornatus* zones, and there is a possible representative of the Fuller's Earth or Fullonian formation. The Upper Lias, as noted by Dr. Kitchin, includes not only the *Communis* zone, but also part of the *Jurensis* zone. *Rhynchonella tetrahedra* is definitely recorded from the Middle Lias, while the Lower Lias includes representatives of the *Capricornus*, *Jamesoni*, and possibly *Oxynotus* zones. No traces of Rhætic beds were discovered, but there was evidence of a good deal more Triassic marl and conglomerate than previously recorded, and these red rocks repose on mudstone, possibly of Devonian age.

At Pluckley the boring, commenced in Weald Clay, proved an unbroken sequence down to the Kimeridge Clay, and at Penshurst, commenced in Hastings Beds, a similar sequence was encountered. In both cases Purbeck and Portland Beds are now distinctly recognized and separated, with considerable increase in thicknesses at Penshurst, but it is admitted that the Portland Sand is represented in the Upper Kimeridge Clay. At Penshurst there are "greater thicknesses of Lower Wealden and Purbeck strata than have been proved at any other place within the Weald". Of Kimeridge Clay 622 feet was penetrated, probably not more than one-half of the total thickness, as the Penshurst site appears to lie near the central part of an old depression where the accumulation of sediment reached its maximum, and it is remarked that upon the thickness of this formation largely depends the success or failure of attempts to reach the Palæozoic floor in the south-east of England. An instructive diagram (plate iv) shows the arrangement and succession of the strata from Penshurst to Dover, and on it thick black lines indicate planes of original horizontality. From these data the earth movements can be studied, and it is apparent that the Wealden dome is "an anticline formed upon, or within the area of, an earlier syncline".

Dr. Kitchin has contributed some judicious remarks on the testimony afforded by fossils obtained from cores and shafts, the depths recorded being no positive indication of vertical range, while at many horizons fossils may occur in proximity to cores that were barren. Observations are made on the influence of sedimentary conditions and on certain species that appear to have a wide range in time. The value of recording generic names alone need not be questioned, as they may help to indicate the conditions under which strata were deposited.

An example may be taken from plate i, in which is figured a species of Pholadidea, the bored crypts of which descend from the base of the Sandgate Beds into the Atherfield Clay. Here the pause in deposition is indicated by the absence of the Hythe Beds, as previously noted.

Interesting lists of fossils are given from various horizons, from the *Mammillatus* Bed downwards, and comments are made on many species in reference to the vexed subject of nomenclature, on records of species new to this country, and on the limits of formations and epochs. The difficulty of fixing a definite plane of division is felt with the Corallian and overlying and underlying strata, as in Dorset; and so also with the Kimeridge Clay and Portland Beds, the French geologists, in their usage of the name Portlandian, having insufficiently realized the limits in the type-areas of England.

II.—Géologie du Bassin de Paris. Par M. Paul Lemoine. 8vo; pp. ii, 408, with 9 plates and 136 text-illustrations. Paris, Hermann & Fils; London, Dulau & Co., 1911. Price 15 fr.

In this well-printed and well-illustrated work the author gives a comprehensive account of the stratigraphy, economic products, zonal palæontology, and physical geography of the Secondary, Tertiary, and Quaternary formations which, in a broad sense, constitute the Paris Basin.

After some preliminary remarks on general geology, he describes the main structural features of the basin. Then follow a short historical summary of the work of previous geologists, from Cuvier and Brongniart (1810) to the present time, and useful particulars of the geological survey maps, with names of the geologists responsible for them.

With the aid of palæographic and other maps and sections, the tectonic structure of the region, the areas of land and water at different periods, and the variations in sedimentary conditions of strata from the Trias onwards are expounded by the author. His objects are to give a faithful account of this interesting and important region from the knowledge scattered in many publications, to verify doubtful points, and where possible to decide differences of opinion. Illumined, as it is, with much additional information derived from the author's own researches, the result may be justly regarded as a standard work for study and reference.

In giving some account of this volume we propose to deal mainly with such points in the classification, nomenclature, and correlation of formations as may be of interest to our readers.

TRIAS. This system is divided as follows:—

Neotrias. Keuper and Marnes irisées.

Mesotrias. Muschelkalk.

Eotrias. Grès bigarré.

RHETIAN (or Rhætic Beds). These are placed independently as Passage Beds, and consist of arkoses, grits, sands, marls, and limestone, with the zonal *Avicula contorta*, also *A. infraliasiana*, *Leda Deffneri*, *Mytilus minutus*, *Myophoria*, *Psammobia*, *Diademopsis Heberti*, etc. We are glad to note the preservation of the name *Avicula contorta*.

LIAS. Four stages are distinguished—

TOARCIAN. This is taken to include the Ammonite zones from that of *Harpoceras falciferum* to that of *H.* (*Lioceras*) *opalinum*, thus including not only equivalents of our Upper Lias but overlying Passage Beds (Midford Sands). It is noted that Professor E. Haug would include higher zones belonging to the basal portion of the English Inferior Oolite.[1]

CHARMOUTHIAN. This is taken to include the Ammonite zones from that of *Ægoceras Valdani* to that of *Amaltheus spinatus*, and is therefore equivalent to the higher part of our Lower Lias and the whole of our Middle Lias. The term Charmouthian is thus inappropriate, as the main portion of the English Middle Lias is not present in the Charmouth cliffs, and moreover the term has been used by Mr. S. S. Buckman for the zones from *Echioceras raricostatum* to *Liparoceras capricornus*. A term taken from a French locality would be preferable for the Paris Basin.

SINEMURIAN. This includes the Lower Lias Ammonite zones from that of *Arietites rotiformis* to those of *A. stellaris* and *A. obtusus*.

HETTANGIAN. This includes the basal Lower Lias zones of *Psiloceras planorbis* and *Arietites Burgundiæ*, and overlying zones of *A. liassicus* and *Schlotheimia angulata*.

A diagram-section from Longwy, west of Luxembourg, to Hirson, west of Mézières, shows the Bajocian overlapping the Toarcian in a westerly direction and resting directly on the Charmouthian. In the Cotentin the Charmouthian overlaps lower beds of the Lower Lias and rests directly on the Trias. Important beds of iron-ore occur in the higher part of the Toarcian in Lorraine in the zone of *Harpoceras* (*Grammoceras*) *aalense*.

LOWER JURASSIC (of author).[2]

BAJOCIAN. This series is rightly taken to include the strata from the zones of *Harpoceras Murchisonæ* and *H. concavum* (grouped together as Aalenian) to the zones of *Cœloceras subcoronatum* and *C. Blagdeni*, with overlying zones of *Cosmoceras Garantianum* and *Parkinsonia Parkinsoni* (grouped all together under the zone of *Oppelia subradiata*).

BATHONIAN. The zonal subdivisions (in descending order) are—

Bradfordian, with *Oppelia aspidoides*, *Œkotraustes serrigerus*, and *Oxynoticeras discus*.

Vesulian, with *Oppelia fusca*, *Morphoceras polymorphum*, and *Perisphinctes zig-zag*.

In Normandy the highest beds are equivalent to the Cornbrash, and the lowest (including the Caen stone) to the Fuller's Earth of

[1] See remarks of Professor J. Welsch, *Geology of Thouars*; noticed in GEOL. MAG., September, 1911, p. 419.

[2] The author regards the Lias as forming a separate system, and he uses the term Lower Jurassic in the sense in which Lower Oolitic is used in England.

England. Representatives of the Forest Marble and Bradford Clay are seen in the Calcaire à Bryozoaires (Pierre de Langrune) with *Dictyothyris coarctata, Magellania digona,* etc.

Callovian and Oxfordian. In this series the grouping in mass corresponds with that in England, but the Callovian is taken to include much more than the Kellaways Beds of this country, the Oxfordian being restricted by the author to the zone of *Cardioceras cordatum.* The intimate connexion between the Bathonian (Cornbrash, etc.) and the Corallian is shown by the fossils recorded from the lower and higher portions of the Callovian and Oxfordian respectively, on the western side of the Paris Basin.

Corallian. This variable series of strata is subdivided as follows, the species of Ammonites taken to mark zones differing from those adopted in England:—

Sequanian: Zone of *Perisphinctes Achilles,* associated with *Zeilleria humeralis.*
Rauracian: Zone of *P. Achilles.*
Zone of *Peltoceras bicristatum* and *Ochetoceras Marantianum.*
Argovian: Zone of *O. canaliculatum* and *Perisphinctes variocostatus.*[1]

The Corallian fossils vary in distribution according to the sedimentary nature of the strata. Thus *Perisphinctes plicatilis* occurs in Argovian limestones in the valley of the Yonne.

Kimeridgian. This includes the following zones:—

Zone of *Reineckeia eudoxus* and *Aspidoceras caletanum* (Upper Virgulian).
Zone of *A. orthocera* and *A. Lallierianum* (Lower Virgulian).
Zone of *Pictonia Cymodoce* (Pterocerian).

Portlandian. This includes—

Zone of *Perisphinctes bononiensis.*
Zone of *Stepheoceras portlandicum.*

It is noteworthy that *Hemicidaris purbeckensis* occurs in higher Portlandian of Haute-Marne and Meuse, where the uppermost strata yield *Pinna suprajurensis, Trigonia concentrica,* etc. In the Boulonnais the highest strata are noted as fluvio-lacustrine with *Physa, Planorbis,* etc., equivalent to part of our Purbeck. In lower stages there occur *Cyrena, Corbula, Trigonia, Perisphinctes giganteus,* etc.

(*To be concluded in our next Number.*)

III.—The Flora of the Raritan Formation. By E. W. Berry. Bull. III, Geol. Surv. New Jersey, 1911. pp. 1–233, with 29 plates.

This noteworthy contribution to the study of the Cretaceous floras of the United States is in the main a revision of Newberry's posthumous monograph, *The Flora of the Amboy Clays.* In addition, several new plants, as well as species from new localities, are described,

[1] This species, described by Buckland as *Ammonites variocostatus* in his "Bridgewater Treatise", is usually spelt *varicostatus* in English works.

and the number of forms now known from the Raritan formation = Amboy Clays is between 160 and 170. The ferns are particularly interesting and varied, several being referred to the genera *Gleichenia*, *Dicksonia*, *Asplenium*, and *Ophioglossum*. The Cycads are represented by numerous members of the genus *Podozamites*, and a species of *Microzamia*. The Coniferæ are referred to the genera *Dammara*, *Brachyphyllum*, *Thuja*, *Sequoia*, and *Widdringtonites* among others. The Ginkgoales are represented by *Baiera* and *Czekanowskia*. Only a single Monocotyledon is recorded, but the Dicotyledons, as is invariably the case in Upper Cretaceous floras, are both very numerous and very varied, and far outnumber the representatives of all other groups. Among the Dicotyledonous leaf-impressions figured are good examples of the leaves of *Magnolia*, *Liriodendron*, and *Sassafras*, as well as those of *Salix* and *Populus*. A general account of the Raritan formation and its correlation is added, and the distribution of the species described, in time and space, is also adequately considered. On the whole the memoir appears to be a sound piece of work, noteworthy in that the author has obviously rejected as unsatisfactory the less perfect specimens in the collections which he describes, and he has thus avoided the common error of making much of material which is often quite unworthy of description.

E. A. N. A.

IV.—Geological Survey of the United States.

WATER-SUPPLY Papers Nos. 263, 266, 267, and 268 (1911) contain accounts of the surface water in the basins of the Ohio, Missouri, Lower Mississippi, and in the western Gulf of Mexico. In the introductory portions of these memoirs there are useful definitions of terms used in hydraulic computations; descriptions of the methods of measuring stream-flow, with illustrations; descriptions of the river basins, with details of gaugings; and illustrations of rivers, waterfalls, canals, wasteway gates, dams, and headworks.

Water-Supply Paper No. 273 (1911) is on the Quality of the Water Supplies of Kansas, by Mr. H. N. Parker, with report on stream pollution through mine-waters, by Mr. E. H. S. Bailey. No. 275 (1911) is on the Geology and Water Resources of Estancia Valley, New Mexico, by Mr. O. E. Meinzer. The physiography and geology of the district are described; there are accounts of wind-deposited clay, of alkali and other soils, and of methods of irrigation. The subjects are illustrated by maps and photographic views.

No. 276 (1911) contains an account of the Geology and Underground Waters of North-Eastern Texas, by Mr. C. H. Gordon, with illustrations and geological map.

No. 277 (1911), on Ground Water in Juab, Millard, and Iron Counties, Utah, by Mr. O. E. Meinzer, contains much interesting information on physiography and geology, on the soils and vegetation, on the relation of rainfall to dry-farming, on the ground and artesian water in igneous and sedimentary rocks, in lakes and valleys, and on desert flats. Springs, hot and cold, and irrigation are dealt with, and there are many illustrative maps and diagrams.

Bulletin No. 479 (1911) is by Mr. Chase Palmer on the Geochemical Interpretation of Water Analyses, and it is pointed out "that the statement of water analyses in a form which does not recognize the *proportional reaction capacity* of the radicles fails to show the chemical character of the waters".

Bulletins Nos. 454 and 456 (1911) contain accounts of the Coal, Oil, and Gas of the Foxburg Quadrangle, and of the Oil and Gas Fields of the Carnegie Quadrangle, Pennsylvania.

Bulletin No. 475 (1911), by Messrs. J. E. Gilpin and O. E. Bransky, gives the results of experiments on the diffusion of Crude Petroleum through Fuller's Earth. It is found that the earth tends to retain the unsaturated hydrocarbons and sulphur compounds in petroleum, and very probably it retains largely the nitrogen compounds in the oil.

V.—Bibliography of the Foraminifera.

Paläontologisch - stratigraphische und zoologisch - systematische Literatur über marine Foraminiferen fossil und rezent bis Ende 1910. Zusammengestellt von Dr. Karl Beutler, Paläontologe in München. (Privately printed and sold by the author, price 3*s*., and postage 3*d*.) 8vo; pp. 144.

THIS is a useful compilation from Woodward, Sherborn, and Tutkovski, with much additional matter, thrown into an alphabetical list and divided up in the last few pages into Geological, Morphological, Systematic, Bibliographical, Geographical Distribution, Catalogues, and other headings, referring the reader by numerals back to the author list of papers. It apparently takes little or no notice of bibliographical details, and omits those painfully brought together by Sherborn, as well as all pagination of the works quoted from. It is also inaccurate in many particulars, notably in the omission of Lister's valuable contribution to the Zoology edited by Lankester, and of any reference to the first edition of Fichtel & Moll, etc. Further, the entry of an author's name as Cuvier, Fichtel, Diesing, Cross, Flint, Schroeter, and so on, is misleading, and only causes confusion. In all works of this nature the full names of the authors are essential, and in most cases easily ascertainable.

The book will be serviceable, however, if carefully used, and we thank Dr. Beutler for putting it together.

VI.—Brief Notices.

1. Thermal Waters in the Yellowstone National Park.—The origin of these waters is discussed by Mr. Arnold Hague (*Science*, N.S., xxxiii, p. 553, 1911), who maintains that they are not primitive in their origin, but are due to vadose or surface waters that have penetrated to a sufficient depth to attain a temperature that would force them again to the surface in the form of boiling springs and aqueous vapours. This conclusion is based on the nature and structure of the rocks through which the heated waters reach the surface, on the mineral constituents of the waters, and those in the sediments and incrustations deposited around springs and pools, and on the composition of the gases.

2. Crinoids.—A Trenton Echinoderm Fauna at Kirkfield, Ontario (Canada, Dept. Mines, Mem. 15 P., 1911), is discussed by Frank Springer. It yielded forty or more species, most of which were originally described by Elkanah Billings, but one is new (*Ottawacrinus billingsi*).

3. Dr. A. H. Clark discusses the systematic position of *Marsupites* in Proc. U.S. Nat. Mus., xl, 649–54, 1911; and Springer has a paper on the Crinoid fauna of the Knobstone formation in the same journal, vol. xli, pp. 175–208. Dr. Clark considers *Marsupites* to have been a pelagic comatulid and compares it and *Uintacrinus* with *Antedon* and other crinoids which have pelagic stages. He insists that *Marsupites* and *Uintacrinus*, unlike *Antedon*, were always, at all stages, free-swimming animals.

REPORTS AND PROCEEDINGS.

Geological Society of London.

January 10, 1912.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communication was read:—

"On a Late Glacial Stage in the Valley of the River Lea, subsequent to the Epoch of River-Drift Man." By S. Hazzledine Warren, F.G.S. With Reports on the Flowering Plants, by Francis J. Lewis, M.Sc., F.L.S.; on the Mosses, by H. N. Dixon, M.A., F.L.S.; on the Mollusca, by Alfred Santer Kennard, F.G.S., and Bernard Barham Woodward, F.L.S., F.G S.; on the Coleoptera, by C. O. Waterhouse, I.S.O., F.E.S.; on the Entomostraca, by D. J. Scourfield, F.R.M.S.; and on the Microscopic Examination of the Sandy Residue, by George Macdonald Davies, F.G.S.

The paper describes a carbonaceous deposit, discovered by the author, which is embedded in the low-level River-Drift gravel of the Lea Valley, in the neighbourhood of Ponders End. It belongs to the close of the Pleistocene Period, and is very much later than the Moustierian deposits. It may be of Magdalenian age, but there is no evidence to suggest this. It is more probably post-Magdalenian, formed during the time of the supposed archæological hiatus between the Palæolithic and the Neolithic Epochs. The deposit yields a varied fauna and flora, which has been the subject of extended investigation. The results of this are embodied in the reports which are appended to the paper. The conclusions arrived at in these reports are in close agreement with each other, and indicate climatic conditions similar to those now found in Lapland. The evidence of this comparatively late Arctic climate in the South of England is important. It throws much light on many vexed questions, particularly with regard to the relationship of Palæolithic man to the Glacial Period. It may have been the Arctic conditions represented by the Ponders End stage (as it might appropriately be named) which caused the migration of Palæolithic man to less inclement regions. The correlation is also suggested between the Ponders End stage and the 'Trail' of the Rev. O. Fisher. The evidence is further interesting, as showing another important fluctuation of climate during the Pleistocene Period.

Mineralogical Society.

January 23.—Professor W. J. Lewis, F.R.S., President, in the Chair.

Miss M. W. Porter and Dr. A. E. H. Tutton: The Relationship between Crystalline Form and Chemical Constitution: The Double Chromates of the Alkalies and Magnesium. The investigation of the crystals of ammonium-magnesium chromate containing $6\,H_2O$, and of those of the analogous salts containing rubidium and cæsium (the formation of the corresponding potassium salt being impossible), shows not only that the double chromates belong to the same monoclinic series as the double sulphates and selenates previously investigated by Dr. Tutton, but that their mutual relationships are precisely parallel to those afforded by the other groups of the series. The rubidium and cæsium salts exhibit the same progressive changes of morphological and physical properties in the same direction as the rubidium and cæsium salts of all the other groups investigated, so that if the potassium salt could be prepared the three salts would undoubtedly form a eutropic group progressive in properties in accordance with the atomic weights of the three alkali metals, and it is even possible to predict the properties of the missing potassium salt. As in all the other cases, the ammonium salt is isomorphous and not eutropic. Moreover, the double chromates are isomorphous and not eutropic with the eutropic sulphates and selenates.—Professor W. J. Lewis: On a lead-grey Sulpharsenite from Binn, probably Liveingite. The crystals have two prominent zones mutually inclined at 90°, the one markedly oblique and the other prismatic in symmetry. Assuming oblique symmetry, the face-symbols are very high numbers; assuming anorthic symmetry, they are simple, but the crystals possess several relations characteristic of oblique symmetry, and twinning, though undoubtedly occurring, is not a satisfactory explanation.—R. H. Solly and Dr. G. F. H. Smith: A new Anorthic Mineral from the Binnental. Since no further crystals have come to light similar to the five minute ones found in 1902 by Mr. Solly on a crystal of, probably, rathite, they have recently been remeasured. They are lead-grey and their streak is chocolate in colour, and they are therefore probably a sulpharsenite of lead. No axes or plane of symmetry were observed, and the symmetry is therefore anorthic. The fundamental constants are $a:b:c = 0{\cdot}9787:1:1{\cdot}1575$; $\alpha = 116°\ 53\frac{1}{2}'$, $\beta = 85°\ 12'$, $\gamma = 113°\ 44\frac{1}{2}'$; $010:001 = 62°\ 41'$, $001:100 = 83°\ 4\frac{1}{2}'$, $100:010 = 65°\ 46'$; and about twenty-one forms were observed, of which the most prominent are 100, 010, 001, $\bar{1}10$, $1\bar{1}1$, $11\bar{1}$.—Dr. A. Hutchinson: On Colemanite and Neocolemanite. By a slight change in the orientation adopted for the crystals of the latter mineral its crystallographic and optical properties can be brought into harmony with those of the former. This can be effected by a rotation of the crystal through 180°, about the normal, to the face 001, 100 of neocolemanite, then coinciding with $\bar{2}01$ of colemanite.—Dr. A. Hutchinson and Dr. A. E. H. Tutton: Further observations on the Optical Characters of Gypsum. With the aid of new apparatus by which the section-plate of gypsum perpendicular to the first median line can be surrounded during observations of the interference figure by flowing hot water, of which the temperature is accurately recorded both immediately before and after passing the crystal, the authors have been able to prove definitely that the temperature at which gypsum becomes uniaxial is for sodium light 91°, for red C and greenish-blue F hydrogen light 89°, and for the violet hydrogen line near G 87°. These temperatures agree precisely with those observed for the exact superposition of the pair of images of the spectrometer slit, afforded by a 60° prism cut to give the α and β refractive indices. Owing to the large correction necessary for conduction of the crystal holder when the ordinary Fuess air-bath heating apparatus was employed, and to the difficulty in determining it, former determinations of the temperature at which a section-plate of gypsum becomes uniaxial were too high, and did not agree with the prism observations.—Dr. G. F. H. Smith: Note on a large Crystal of Anatase from the Binnental. The crystal exhibits a combination of the forms *a* (100), τ (313), and *z* (113), and the others not prominent, and it is remarkable for the fact that the faces τ have been entirely replaced by numberless tiny crystals with the forms *z* (113), *k* (112), *p* (111), and *e* (101), and the same orientation as the large crystal.

CORRESPONDENCE.

THE DRAWING ON A RED CRAG SHELL.

Sir,—I think we shall do well to be cautious in recognizing a "long-lost brother" in the Red Crag, though his credentials have been accepted by no less an authority than Sir E. Ray Lankester. At any rate I doubt whether the carving on a shell of *Pectunculus glycimeris*, cited in your last number by Dr. M. C. Stopes, strengthens the evidence in favour of his existence. I had the opportunity of examining this a few years ago and possess a photograph, which Mrs. Stopes kindly gave me at that time. The design and execution of the engraving reminded me rather of a piece of grotesque, dating from the nineteenth century, than of the efforts of Palæolithic man, as displayed on the walls of caves or in other relics of his handywork. That, however, is a matter of opinion, but what weighed even more with me when I examined the specimen was the state of the shell and the carvings. The former, especially its hinge-teeth, showed the very slight corrosion usual in Crag specimens of this *Pectunculus*, while the surface of the carved parts was smooth and comparatively fresh-looking. I do not doubt that the late Mr. Stopes was convinced that he had obtained possession of a genuine relic of Red Crag Man, but, if we could trace out the history of the specimen before it came into his hands, I think we should find this another instance of an "old friend with a new face".

T. G. Bonney.

STRATIGRAPHICAL NAMES.

Sir,—It is probable that few geologists whose studies are limited to a single country, or even to a single continent, have any adequate conception of the large number of names that have been proposed either for geological formations or for periods of geological time.

I do not myself know how many such names there are, but my card-index to them, incomplete though it unfortunately is, already extends to a thickness of over two yards. From this simple fact certain consequences follow.

In the first place it is impossible for those of us who have to deal with formations of every age and from all quarters of the globe to carry in our heads the numerous names that have been proposed for them. A card-index, such as that to which I have referred, is an almost indispensable aid to one's work, and it is very necessary to keep it up to date. But since few workers possess such a card-index, there is an ever-increasing chance that those names which are yearly, one might say daily, proposed, will be already utilized in some other sense. New names continue to appear in all languages and in publications of most diverse standing, including many that have an extremely limited and local circulation. And just as there is no restriction on the part of publications, neither does there seem to be any on the part of the worker who thinks himself entitled to propose such new names. Not only are they proposed by recognized official bodies, such as national surveys, but also by individual geologists of every degree of competence. Thus, the chances that the names will be unsuitable at the outset and overlooked afterwards are greatly increased.

To give one or two examples out of many—a British geologist, familiar with the Bradford Clay and with the time-name 'Bradfordian', proposed by Desor in 1859, would not be likely to understand or to sympathize with a modern American proposal to apply the same term to some Lower Carboniferous beds in New York. Again, a French or German geologist who has been taught that the term 'Stonesfield slate' denotes certain 'schistes jurassiques inférieures d'Angleterre', runs the risk of being considerably misled when, in a recent memoir on the geology of Jura and the surrounding districts, he comes upon the term 'Stonefield schists' applied to some metamorphic rocks of considerably greater age.

Now, Sir, the object of this letter is not merely to indulge my love for a grumble, but to suggest to the geologists of Britain, at any rate, two ways by which they might help themselves and others.

A paper recently issued by an American colleague states that certain formational names therein proposed have previously been submitted to an official committee on Geological Nomenclature, and have received its approval. Would it not be possible to have such a committee in this country, nominated, perhaps, by the Geological Survey and the Geological Society? The decrees of a committee, however authoritative, could have no binding force, but its existence might act as a deterrent to the irresponsible and as an aid to the conscientious worker. It would be the business of the committee to make itself familiar with the names already proposed in this and other countries, and to prevent such sources of confusion as the two mentioned above.

The second suggestion is that every British geologist who proposes a new name, whether it be in a memoir of the Geological Survey, in the Quarterly Journal of the Geological Society, or in the Proceedings of the Little Muddleborough Field Club, should be invited to send the name, together with a definition, to the Editor of the Geological Magazine. These names might be combined into a single list at the end of each year, or possibly published at more frequent intervals, according to the discretion of the Editor. It may, perhaps, be pointed out to me that, since the International Catalogue of Scientific Literature has a section for Geology, that would be the proper place for indexing such names. Agreed! But all the same the suggestion is not a practical one so long as that particular volume of the International Catalogue is thrown together (one cannot say 'edited') on its present lines.

These proposals are the best that occur to me at present. Should they give rise to any discussion and to any better proposals, I shall be glad; but whatever be the upshot of discussion I wish to insist that it is really time for something to be done.

F. A. Bather.

OBITUARY.

GEORGE MAW, F.L.S., F.S.A., F.G.S.

Born 1832. Died February 7, 1912.

The death is announced of George Maw, at Benthall, Kenley, Surrey, and formerly of Benthall Hall, Broseley, Shropshire, aged 79. Mr. Maw, who for many years was a manufacturer of encaustic tiles at Broseley, took an early interest in geology, became a Fellow of the Geological Society in 1864, and a valued contributor to the pages of the Geological Magazine, from the first volume in 1864 to 1878.

His first communication, read before the Geological Society in 1864, was on the drift-deposits of the Valley of the Severn, and it was followed by one on the potter's clay of Fremington near Barnstaple, a deposit which Maw was disposed to regard as of Glacial age. In 1865 he described in the Geological Magazine some deposits of Chert, White Sand, and White Clay, which occurred in pockets in the mountain-limestone of Llandudno. In 1867 he brought before the Geological Society observations "On the Sources of the Materials composing the White Clays of the Lower Tertiaries", and in the following year a paper "On the Disposition of Iron in variegated Strata", illustrated by coloured plates and many diagrams and analyses. This undoubtedly was his most important contribution to geological science, and arrested the attention and won the warmly expressed admiration of Professor Ruskin, who was enchanted with the beauty of coloration and variegation in arrangement and banding displayed in the sections illustrating this very valuable work.[1]

In 1876 he published in the third edition of the Catalogue of Specimens of British Pottery and Porcelain in the Museum of Practical Geology, an instructive and practical appendix on a series of specimens which he had collected in order to illustrate the Clays and Plastic Strata of Great Britain.

[1] See Quart. Journ. Geol. Soc., vol. xxiv, pp. 351–400, pls. xi–xv, and 24 woodcuts, 1868.

Many other subjects attracted the attention of Maw: thus in 1870 he drew attention (Geol. Mag.) to the occurrence of Rhætic beds in North Shropshire and Cheshire.

George Maw was also a most accomplished botanist, and his great monograph on the genus *Crocus* (with an appendix by C. Lacaita) deserves special notice. In it he gives coloured figures of every species from actual specimens grown and flowered at Benthall. To obtain these and to study their geographical distribution, he travelled over the whole of Europe and North Africa as far as the genus extends. (See his monograph of the genus *Crocus*, with an appendix; pp. viii, 326, xx, and 67 plates coloured. 4to. London, 1886.)

In 1871 he accompanied Dr. (afterwards Sir Joseph) Hooker to Morocco and the Great Atlas, and communicated the results of his geological researches early in the following year to the Geological Society. Two years later he made a journey from Algiers to the Sahara, and the record of his observations was published by the same Society. In 1886, on account of ill-health, Maw gave up his business, and lived in retirement at Kenley in Surrey.

MISCELLANEOUS.

Mr. A. F. Hallimond has been appointed to the assistant curatorship of the Museum of Practical Geology, in succession to Mr. W. F. P. McLintock, who has been transferred to the geological department of the Royal Scottish Museum, Edinburgh.—*Nature*, January 4, 1912.

Bolitho Medal.—We learn from *Nature* that the Royal Geological Society of Cornwall at its annual meeting on October 31 presented the Bolitho gold medal to Mr. Clement Reid, F.R.S., in recognition of the able and conscientious manner in which he had superintended, during the past ten years, the geological resurvey of the county.

Last year's Medal was presented to Dr. G. J. Hinde, F.R.S., for his important researches in the palæontology of the Older Rocks of Cornwall.

Sedgwick Museum, Cambridge.—The presentation of the testimonial to Mr. Henry Keeping on his retirement from the post of Curator of the Geological Museum, Cambridge, took place in the Sedgwick Museum on Saturday, December 2. In handing Mr. Keeping the purse for £75 1*s.* 6*d.* with the list of subscribers, Professor T. McK. Hughes referred to the valuable services which Mr. Keeping had rendered to the geological department during the fifty years which he had spent at Cambridge, commencing under Professor Sedgwick. His skill and energy in collecting fossils had been remarkable, and the material he had brought together, especially from the Tertiary beds, had greatly enriched the Museum. Mr. Keeping, in returning thanks, expressed his deep appreciation of this recognition of his work by old friends and students from all parts of the world, and gave some interesting reminiscences of the condition and size of the collections in the old Woodwardian Museum when he first entered upon his duties as Curator.

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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. IV.—APRIL, 1912.

ORIGINAL ARTICLES.

I.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from the January Number, p. 8.*)

(PLATE VII.)

ONE of D'Orbigny's subsidiary methods of classification was to create separate genera for those species which heap layer upon layer of zoœcia by prefixing '*Mult*' or '*Multi*' to the name of the genus to which they would but for this habit of growth be referred. It is rather surprising that he did not have occasion to create a genus *Multeschara*, as there are two species in the English Chalk which he could only have dealt with in this way. They are of interest in their bearing on the question of the admissibility of methods of growth in classifying the Cheilostomata, as they are linked together by a most adventitious peculiarity in growth and one which does not involve any zoœcial modification. They offer therefore a case in which, if those who will not allow to zoarial growth any measure of classificatory value are right, it might be anticipated that species so linked together would be a heterogeneous assembly and not even consistent in this habit of growth. Such an anticipation would hardly be borne out in the case of the English Chalk. The Multescharine habit is practically confined to the two following species, which are most distinctly homogeneous, and neither of which, as far as my experience goes, ever adopts any other mode of growth (except for occasional specimens of *Rhagasostoma palpigerum* of purely Escharine habit, which may fairly be regarded as cut off prematurely in the Escharine stage, through which every '*Multeschara*' must pass). The only other Escharine species which I have ever found in Multescharine habit is the very common form usually labelled *Eschara* (or *Onychocella* or *Rhagasostoma*) *Lamarcki*, Hag., but which I strongly believe to be the original *Eschara irregularis*, Hag.,[1] although neither the figure nor the description is conclusive. After a severe struggle for existence in the zone of *Terebratulina lata* this species rapidly becomes abundant in the Senonian stage, and in its vigorous youth in the zone of *Holaster planus* it frequently assumes a Multescharine habit; but this

[1] Hagenow, *Jahrbuch für Mineralogie*, 1839, p. 264, pl. iv, fig. 2.

development would seem to have proved unprofitable, as it is not repeated, so far as I know, at any later horizon, although the species persisted in Escharine habit to the top of the English Chalk in unabated abundance. But even if this species were grouped on account of its early behaviour with the two following, the group so constituted would be still quite homogeneous, though not so strikingly.

Had a genus *Multeschara* been in existence I should have gladly referred my new species to it, for they are so notably smaller than the average run of Escharine forms that such a treatment would have recognized a very large measure of common zoœcial as well as zoarial character. As it is they are zoœcially Rhagasostomata, and I leave them there.

RHAGASOSTOMA SUSSEXIENSE, sp. nov. (Pl. VII, Figs. 1–6.)

Zoarium concentrically multilaminate, branching and very massive; the section figured, which is about 4 cm. in its narrowest dimension, is from a specimen little above the average.

Zoœcia subpyriform, very small, ranging freely in length between ·32 mm. and ·38 mm.; aperture semicircular, with a short rectangular tongue about three-fourths of the width of the aperture projecting into it from the lower margin, leaving a wide deep sinus at either end.

Oœcia very doubtfully present; but a rounded depression occasionally observable at the lower end of a zoœcium may be a relic of an oœcium connected with the preceding zoœcium.

Avicularia shuttle-shaped, with the front wall between the apex and the aperture flush with the side walls; the aperture is central and shaped like a rounded arrow-head, and the sinus which forms the stem of the arrow-head is very narrow and ends in a tiny circular pore.

The species is very prone to ectocystal development; Fig. 4 shows a specimen in which the avicularia dwarf the zoœcia, Fig. 5 a specimen in which the reverse occurs.

Abundant at Seaford and Beachy Head in the upper part of the *M. cor-testudinarium* zone (= Rowe's lower one-fourth of the *M. cor-anguinum* zone), but very difficult to clean perfectly, the chalk being tenacious. I have not yet observed it elsewhere.

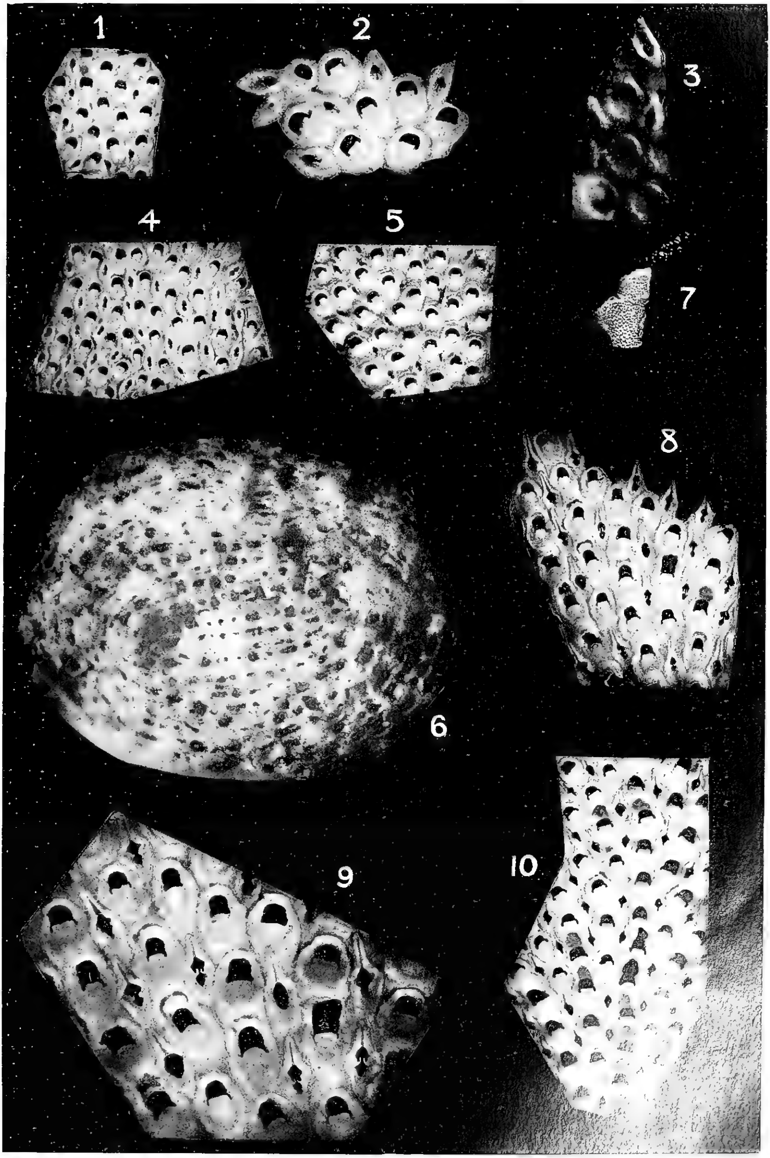
RHAGASOSTOMA PALPIGERUM, sp. nov. (Pl. VII, Figs. 7–10.)

Zoarium branching, with wide but flattish and rather fragile stem.

Zoœcia small, very variable in dimensions, ·4 mm. being a fair average length, but ·35 mm. on the one hand or ·5 mm. on the other being easily found; aperture heel-shaped, with a slightly incurved lower margin; from its corners two long and narrow slits run in a direction at first outwards and downwards, but quickly bending round to straight downwards; the zoœcia remain always distinguishable from one another.

Oœcia large, rather straight-sided, very high at the apertural end, which is heavily cut back, giving a deeply concave free edge.

Avicularia angular, widest round the aperture, with a long, slender, tapering beak with a median furrow; the aperture is roughly



R. M. Brydone, Photo. Bemrose, Collo.

Chalk Polyzoa.

diamond-shaped, with the lower part of the diamond more obtuse-angled than the upper; from the lower angle of the diamond there descends what is probably a fairly wide straight-sided slit, but its edges seem always more or less broken away; in the best-preserved specimens two long and very slender feeler-like processes project into the aperture from either side of the upper end of the slit; when all the fragile part has been broken away the aperture is enlarged into a fairly symmetrical diamond.

This species is very strongly associated with the subzone of *Offaster pillula* (in the zone of *Actinocamax quadratus*) and the immediate neighbourhood of that horizon, occurring with great constancy, though always scarce. Otherwise I have only found it in the *Uintacrinus* band in Hampshire and Kent and in the *Marsupites* band in Hampshire, and then only most exceptionally.

EXPLANATION OF PLATE VII.

Fig. 1. *Rhagasostoma Sussexiense.* Part of a branch. × 12.
,, 2. Ditto. Another part of the same branch. × 21.
,, 3. Ditto. The same specially lighted to show up the outlines of the zoœcia and avicularia.
,, 4. Ditto. Part of another branch. × 12.
,, 5. Ditto. Ditto. × 12.
,, 6. Ditto. Cross section through a branch. × 12.
,, 7. *R. palpigerum.* A fragment of a large zoarium from the *Uintacrinus* band, Margate. Nat. size.
,, 8. Ditto. Part of the same. × 12.
,, 9. Ditto. Ditto. × 21.
,, 10. Ditto. Part of a branch from the subzone of *Offaster pillula*, Seaford. × 12.

(*To be continued.*)

II.—The Classification of the Rocks of the Western Australian Goldfields.

By J. Allan Thomson, B.A., B.Sc., F.G.S.

Contents.

I. Objects of this Paper.

THANKS to the descriptions published by visiting mining engineers and the more detailed work of the Geological Survey of the State, the general geological features of those parts of Western Australia in which mining is carried on are now well known. A surprising degree of uniformity of geological structure and mode of gold occurrence is revealed over an extent of country unparalleled elsewhere in the world. And yet it is safe to assume that to the casual reader who has not visited the country the above publications present little else than a mass of bewildering detail.

"For reasons which can be readily understood, geological inquiry in Western Australia has up to the present consisted chiefly of a series of unconnected observations to the co-ordination of which we must look to the future."[1]

One reason for this, as outlined below, is the difficulty of field geology. A more important reason is the poor measure of comparative petrological study hitherto attempted, and the failure to use those principles of classification that have been worked out in areas of crystalline schists in Europe and America. The object of this paper is to give the main results obtained by the writer's petrological studies and to put forward as a working hypothesis a classification of the rocks which will serve as an introduction to a detailed discussion of each group in subsequent papers.

II. Difficulties of Field Geology in Western Australia.

The greater part of the State possesses an arid, if not a desert, climate, and shows, in consequence, surface features very different from those familiar in more humid regions. The most striking of these is the poor development of drainage systems in the whole region south and east of the Murchison River. On most maps there are no rivers shown within this area except in the immediate coastal districts, but large and small lakes are depicted in great profusion.[2] These lakes on inspection prove to be for the most part mere sandy depressions almost devoid of water except for a few weeks after a downpour of rain, and at other times containing only isolated pools of saline water. They are not, however, disconnected basins, for they pass at each end into dry valleys, and are clearly relicts of a former drainage system. Topographical maps of the heart of the country do not exist, so that it is at present impossible to reconstruct the earlier system and show how the lakes are connected. So flat are the present valley bottoms that it is difficult at times to say which way the present drainage runs.

The general surface of the country is remarkably monotonous. Low ridges and valleys follow one another like the waves of the sea. The valleys are rarely V-shaped or gorge-like, and most often show curves approaching those of the vertical section of a saucer. Only rarely does a dome-shaped mountain rise above the general level of the plateau.

There is a large body of evidence to show that the present surface has originated by the filling in of the valleys from one much more deeply dissected. Not only is this suggested everywhere by the cross-sections of the valleys and the alignment of the lake-basins, but it is proved in many localities by the mining of deep leads to some hundreds of feet below the surface of the present valley bottoms

[1] A. Gibb Maitland, Ann. Rep. Geol. Surv. Western Australia for 1910, Perth, 1911, p. 12.

[2] Cf. H. P. Woodward, "The Dry Lakes of Western Australia": Geol. Mag., Dec. IV, Vol. V, p. 363, 1897.

(e.g. Kanowna). The material filling the valleys is not, however, all or mostly of an alluvial nature. The sands which cover the lake-beds are largely wind-blown, and the same is true for much of the coarser material in the upper parts of the valleys. The whole area is swept by strong cyclonic winds, which convey the material broken by the usual agencies of desert erosion into the nearest hollows, while the finer sand is driven on to the lowest depressions, the lake-beds.

The arid climate has influenced the surface features in yet another way. The ground water level is deeper than is usual in more humid regions, and consequently oxidation of the rocks has proceeded to greater depths. This is especially the case in heavily mineralized belts, where the production of sulphuric acid from the sulphides has given the descending waters stronger powers of attack. The result is the rotting away of large bodies of rock and an increased efficacy of wind erosion. Side by side with the destruction of the solid rock has gone on a reconstruction of surface deposits of various kinds—laterites, surface quartzites, 'cement,' and 'cement gravel'. The laterites are predominatingly aluminous where resting on granite or gneiss, and ferruginous where resting on basic rocks. Owing to their hard nature, they now form the caps of many of the smaller hills and ridges. The 'cement' consists of oxidized rock fragments bound together by a calcareous matrix. The 'cement gravel' consists of rounded or ellipsoidal balls of reddish-white material, which when broken shows a concentric structure. It appears to consist mainly of calcite, but whether the balls have formed by accretion or by replacement is not quite certain. The 'cement gravel' is equally abundant on the sides of the ridges and in the valleys.

In consequence of the large areas occupied by the clastic materials filling the valleys, the deep-going oxidation of many of the rocks, and the widespread covering of surface deposits, the opportunities of examining the solid rocks are greatly curtailed. The rock, if it may be called rock that is at the same time hardest and least subject to oxidation, is jasper, and this forms the summits of many of the ridges. Other ridges are formed of practically unoxidized amphibolites or serpentines. Geological mapping is only possible by the acquisition of a local knowledge of the nature of the oxidized products of known rocks, and by inference from the surface deposits and the plant œcology. The study of rock contacts is seldom possible. Under all the circumstances it is no matter of surprise to find that our knowledge is practically confined to the immediate vicinity of the goldfields, where the underlying rocks are exposed by mining and prospecting operations.

III. General Statement of the Problem, and Discussion of Previous Literature.

With few exceptions the gold-bearing deposits are enclosed within basic schistose rocks, which are foliated in a general north-south direction and are highly inclined. The direction of foliation varies from N.E.–S.W. to N.W.–S.E. The schistose rocks alternate with, or enclose, lenticles of more massive rocks of similar composition.

In some districts there appear also to be sedimentary rocks associated with them. The whole complex is generally referred to as the 'Auriferous Series'. All these rocks occur in relatively narrow belts, separated by wider belts of granite and gneissic rocks, which when foliated possess the same general direction of foliation. All these belts possess a trend, so far as known, parallel to the foliation. Within the auriferous belts in almost every goldfield there are elongate lenticular bands of ferruginous and non-ferruginous jaspers and graphitic schists which also follow the same lines of trend. In most fields there are relatively unaltered intrusive rocks of various natures, viz. felsites, porphyries, porphyrites, and more basic rocks, which in some cases run parallel to, and in others cross, the direction of foliation.

A peculiar feature of many of the schistose rocks of the State is that when cut in depth by mining operations they are frequently stated to be quite massive.[1] In some cases this statement may be based on a faulty correlation: the shafts may pass through a band of schist into an unsheared phacoid of massive rock of similar constitution to the schists. It is, however, undoubtedly the case that many rocks which are apparently quite massive when mined, develop a latent schistosity after some years' exposure in mine dumps, and since this is so it is also reasonable to admit that this latent schistosity may be developed in the weathered parts near the surface. Dykes of sericite schist not unfrequently pass in depth into massive porphyries.

H. P. Woodward[2] in 1895[3] relegated these rocks to the Archæan, and divided them into granites, gneisses, and schists. He described the existence of six great belts crossing the country from sea to sea in a north–south direction. Commencing from the west coast near Perth, these belts are consecutively 'crystalline', 'crystalline', granite, western auriferous belt, granite, and eastern auriferous belt. The relationship of these belts to one another is not clearly indicated, but apparently he recognized that the granites are intrusive into the auriferous series, for he mentions that the western auriferous belt is broken and faulted by granite and diorite dykes. Subsequent observations have been very largely confined to the auriferous belts, and do not seem to have greatly modified Woodward's statement. A seventh belt of gneiss-granite has, however, been recognized on the eastern boundary of the Coolgardie–Kalgoorlie belt by Gibson.[4] A map of the State embodying the recently acquired knowledge is a great desideratum.

Much of the earlier literature relates to the Coolgardie Goldfield and its immediate surroundings, but is, unfortunately, of a very vague character. Coolgardie is situated on the contact zone between a granite on the west intrusive into the auriferous series in the east.

[1] Bull. xxii, pp. 15, 16, 1906. In this and subsequent references 'Bull.' stands for Bulletin of the Geological Survey of Western Australia.

[2] *Mining Handbook to the Colony of Western Australia*, Perth, by Authority, 1895, pp. 37, 38.

[3] The writer has not had access to Government publications prior to 1894.

[4] C. G. Gibson, Bull. xxiv, pp. 29, 30, 1906, and Bull. xxxvii, p. 23, 1909.

The granite along its margin is distinctly gneissose, while the result of contact alteration has been to reconstitute the basic rocks into well-foliated schists. Göczel[1] and many other observers supposed the granite to be a basal Archæan series on which the younger auriferous series was deposited as lavas and tuffs. Chewings[2] in 1896 and Blatchford[3] in 1899 clearly recognized the intrusive nature of the granite, and since that time granites intrusive into the auriferous series have been recognized over the whole length and breadth of the State. But at the same time the distinction between these granites and older gneisses has not always been held in view. Each of the main rock-series will now be briefly reviewed.

Gneisses.—The gneisses have not hitherto received any petrographical or chemical study. Their presence is noted in the Northampton Lead and Copper Field by A. Gibb Maitland.[4] The rocks are briefly described as "granites, gneisses, mica schists and quartz schists, etc., intersected by veins and masses of pegmatite".

"Sheeted zones of micaceous and garnetiferous schist and of garnetiferous gneiss stand out in bold relief with a general north-west and south-east trend." Maitland at one time believed the oldest rocks of the Pilbara District to be "granites and gneisses which form the platform upon which the oldest formations were laid down, and which everywhere underlie the plain extending from Port Hedland to Doolena Gorge on the Shaw River".[5] In a later publication, however, he concludes that the granite and gneisses are everywhere intrusive into the greenstones and associated beds,[6] so that it is doubtful whether any basal gneisses outcrop in the Pilbara District.

H. P. Woodward has described the occurrence of a series of gneisses, mica-schists, sericite schists, and quartzites in the Menzies Goldfield, but does not indicate very clearly whether he regards these rocks as older than, contemporaneous with, or younger than the amphibolites of the auriferous series.[7]

The Greenbushes Tinfield appears to be the chief mining area where pre-granitic gneisses and greenstones exist side by side, but again their relationship to one another is not clearly indicated. Woodward[8] describes the 'Crystalline Series' as consisting of gneisses merging in places into dark-coloured mica-schists, and intersected by dykes of albite-pegmatite, and basic rocks consisting of highly weathered hornblende and mica-schists, penetrated by dykes of highly foliated granite which are in turn penetrated by pegmatites. Dykes of bronzite-diabase intersect both gneisses and basic schists, but their relationship to the pegmatites is doubtful.

Numerous references to gneiss and gneissic granites in the Gascoyne, Ashburton, and West Pilbara Goldfields are made by Maitland,[9] but none of these are sufficiently definite for our present purpose. It

[1] G. Göczel, Interim Report, Dept. of Mines, W.A., for half-year ending June 30, 1894, pp. 18–23, Perth, 1894.

[2] C. Chewings, Proc. Roy. Col. Inst., London, vol. xxvii, pp. 263–371, 1896.

[3] Torrington Blatchford, Bull. iii, p. 20, 1899.

[4] Bull. ix, p. 9, 1903.

[5] Bull. xv, p. 10, 1904.

[6] Bull. xxiii, pp. 79, 80, 1906.

[7] Bull. xxii, pp. 14–16, 1906.

[8] Bull. xxxii, pp. 26–30, 1908.

[9] Bull. xxxiii, 1909.

can hardly be doubted, however, from the numerous references to extensive tracts of gneiss and gneissic granites outside the actual mining fields of the State that there is a fundamental system of Archæan gneisses similar to that of most other parts of the world, and probably of earlier age than the auriferous series. Seeing that so many of the granites are known to be intrusive into the auriferous series, it is remarkable that the distinction between newer granites and older gneisses has not been more clearly held in view by the officers of the Geological Survey of the State,[1] particularly as the former are intimately connected with the gold occurrences, and the latter, except where intruded by later granites, are free of all economic minerals.

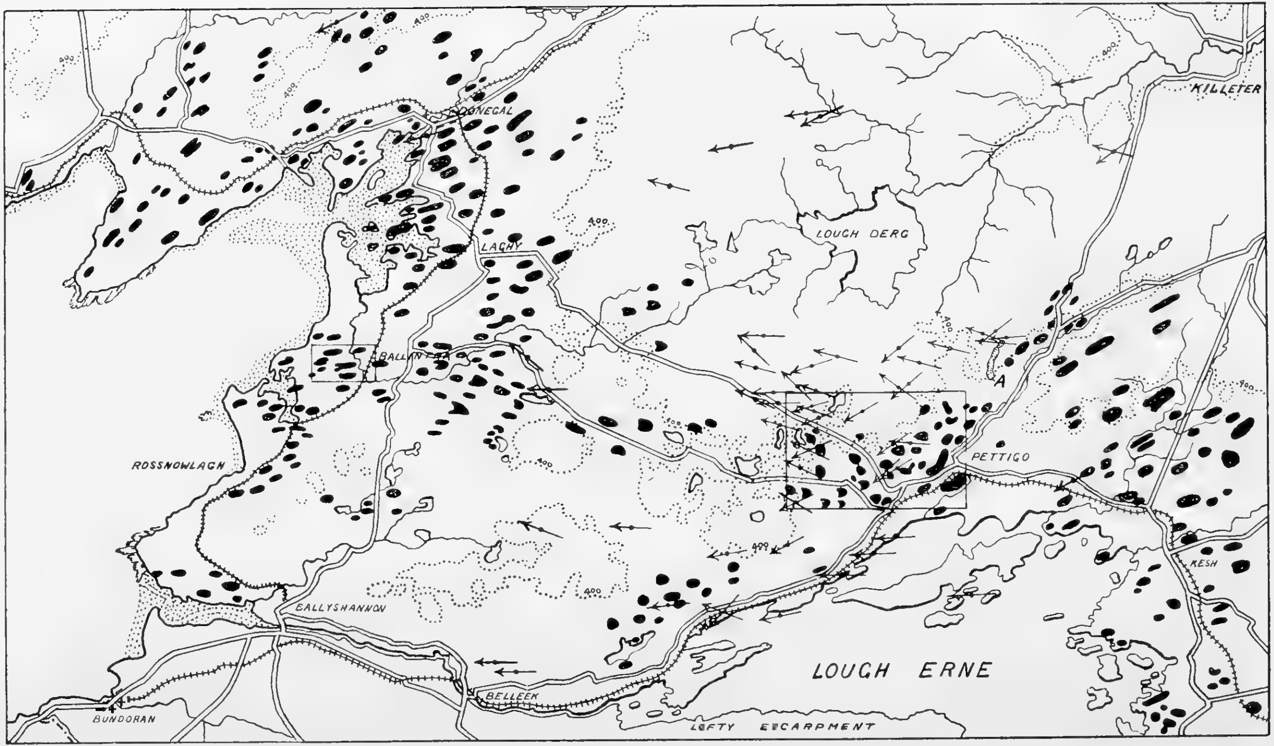
The Auriferous Series.—The rocks of this series are wonderfully uniform both in original petrological nature and in their present state of alteration over the whole State, and it is a perfectly justifiable assumption to regard them as of similar age. A large series of reliable chemical analyses has been made of them, but the accompanying petrological study has been very meagre, and vitiated by a lack of comparative studies. In most of the Bulletins of the Geological Survey it is briefly stated that the rocks are of the general type common to the goldfields of the State, and they are divided into massive and foliated varieties, and again into coarse-grained and fine-grained. Excellent petrological studies were carried out by Vogelsang[2] in 1897, and he showed that some at least of the amphibolites had originated from 'diabases'. Yet in spite of this and of the numerous analyses, the opinion is still occasionally put forward that the series may be of sedimentary origin. Vogelsang has, however, generally been followed by Simpson and Gibson, who have described more massive varieties as epidiorite, diorite, and amphibolites after 'diabase' and pyroxenite, and chloritic and sideritic rocks derived from amphibolite. No attempt has been made, except in Kalgoorlie, to map the various members of the series separately. It is greatly to be hoped, now that a petrologist has been added to the staff of the survey, that this will be attempted in all the principal goldfields, for otherwise the geological maps produced are practically valueless to the mining community.

The banded jaspers or 'ferruginous quartzites' which penetrate the amphibolites and hornblende schists of the auriferous series are generally admitted to be of the nature of lode formations or bands of highly replaced rocks. That they are anterior to the main deposition of the gold is also generally recognized.

The Granites and accompanying Dykes.—The granites generally form the boundaries of the auriferous series, and have seldom, therefore, been completely mapped. The smaller intrusions appear to be boss-shaped, while the larger ones are aligned in N.–S. bands. At the junction the auriferous series is almost invariably represented by well-foliated hornblende schists, whose foliation is parallel to the line

[1] Witness the practice of depicting granites known to be intrusive as 'Gn.' on the geological maps.

[2] K. Schneisser and K. Vogelsang, *Die Goldfelder Australasiens.* English translation, *The Goldfields of Australasia*, H. Louis, London, 1898.



Map of South Donegal showing the distribution of Drumlins.

of junction. That the granite has exercised a distinct contact action on the auriferous series is not generally recognized. The accompanying dykes are sometimes considered to be a later series, where they cut both the granites and the hornblende schists, but this, of course, is not a necessary assumption, for practically all granites are cut by dykes belonging to the same general series of intrusions. The granites have received a little petrographical treatment, but no classification of them into groups has been attempted. The accompanying dykes consist of fine-grained granite, granite porphyry, quartz porphyry, and 'felsite'. For the most part they follow the direction of foliation or are slightly oblique to it.

Granites of more than one age are occasionally recognized in the same field. Thus, near Mt. Percy in the Edjudina District, North Coolgardie Goldfield, Maitland describes a foliated granite (apparently intrusive into greenstone) and a later unfoliated granite.[1] In the North Murchison Goldfield, also, Gibson considers the granites of two ages, a younger undoubtedly newer than the greenstones, and an older of doubtful age.[2] In the Stannum Group of the Woodgina Tinfield, Pilbara Goldfield, Maitland recognizes an area of intrusive porphyry which is of later date than the greenstones and older than the granite and pegmatite veins.[3]

The close association between the intrusion of the granites and the deposition of the gold has been frequently, if not very clearly, indicated. The majority of the smaller goldfields are situated within the contact aureole of the granites, and many reefs are directly associated with dykes of 'felsite'. In a few fields the gold deposits are found within the granite itself. In other cases it is found that the deposits are intersected by dykes of acid rock.[4] The close association of tin and tantalum with albite-pegmatite is very clear.

(To be concluded in our next Number.)

III.—The Drumlin Topography of South Donegal.

By W. B. Wright, B.A., F.G.S.

PLATES VIII AND IX.

(The observations relating to the Pettigo area are communicated with the permission of the Director of the Geological Survey of Ireland.)

MOST people who have lived in strongly glaciated countries are familiar with the topographic features known as drumlins. They are more or less elongated hills of boulder-clay with their long axes parallel to the direction of ice-motion. The literature dealing with them is extensive, but for the most part rather unsatisfactory. Their mode of formation is entirely a matter of speculation and is likely to remain so. There is every reason to believe they are deep-seated products of the ice, so that observation of the process in modern ice-sheets is impossible. The only available means of getting at the

[1] Bull. xi, p. 30, 1903.
[2] Bull. xiv, p. 13, 1904.
[3] Bull. xxiii, p. 61, 1906.
[4] Gibson, Bull. xii, p. 11, 1904.

truth is by careful observation of the peculiarities of form and structure exhibited by these features in the areas where they are most characteristically developed.

Two such areas occur in the south of the county of Donegal in the north-west of Ireland, and were examined by the writer in the summer of 1910. They are both lowland districts formed of Carboniferous rocks, the first lying around the village of Pettigo, north of Lough Erne, and the second around the towns of Donegal and Ballintra. These areas are separated by a ridge of high moorland formed of metamorphic rocks and indicated by the course of the 400 foot contour shown on the map on Plate VIII. Such striæ as have been recorded in the district are also indicated on this map, and it will be seen that their direction corresponds very well with that of the adjoining drumlins.

In the district lying south-east of the moorland there are several rather distinct types of drumlin topography. To the north-east of Pettigo elongated hills occur with axes trending south-west. Some of these are composed entirely of drift, but others appear to be moulded on solid cores of rock, and in general in this area it is difficult to pick out the solid features from those due entirely to deposition. The

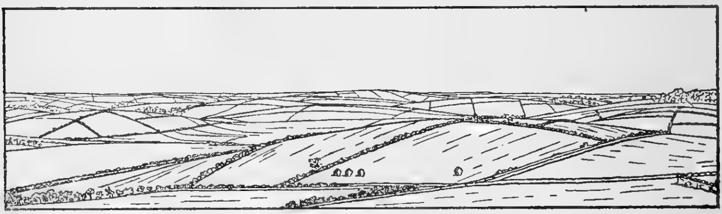


FIG. 1. View looking south-east from Carn Upper, near Pettigo, co. Donegal, across the direction of ice-motion. Gently domed drumlins of shortly oval outline.

country is deeply grooved and ridged in the direction of the ice-motion, which, there is every reason to believe, was just here more constant in its trend than further south-west. Such undoubted drumlins as occur are elongated and of the form most aptly described as hog-backed. Occasionally they show a tendency to develop a crested form similar to that of the drumlins of the Ballintra district to be described below. Immediately around Pettigo the predominant form of ground-plan is a short oval, and the tops of the hills are gently domed without any trace of a central ridge or crest. In Fig. 1 an attempt is made to portray this type of drumlin topography, and the contours on the east of the map in Fig. 2 also show well the character of a number of drumlins of this type. Further west in the neighbourhood of Carntressy and Belalt a third type of topography is in evidence. The drumlins here, like those of Pettigo, are subdued and gently domed in profile, but in ground-plan they take on most remarkable triangular and crescentic forms, which are well shown by the contours in Fig. 2. As the striæ in this area prove two directions of ice-motion, and as the sides of the triangles and the horns of the crescents are parallel to these two directions, one is irresistibly forced to the conclusion that the form of these drumlins is the result of a change in the direction of the ice-flow. There is a certain similarity to the crescentic sandhills known as barkhanes, the concave sides of which face away from the prevalent winds.

In the case of these sandhills, however, there seems to be no necessity for any change in the direction of the wind, the cusps being built up by the natural creep of the sand round the flanks rather than over the crest. This flanking action, though no doubt occurring to a slight extent in the case of ice-motion, is not likely to have any powerful effect. Moreover, there certainly seems in the present case to be a distinct connexion with change in the direction of flow.[1]

If now we cross over to the second district, which lies to the north-west of the metamorphic moorland, in the neighbourhood of Ballintra, Laghy, and Donegal, we find quite a different type of topography.

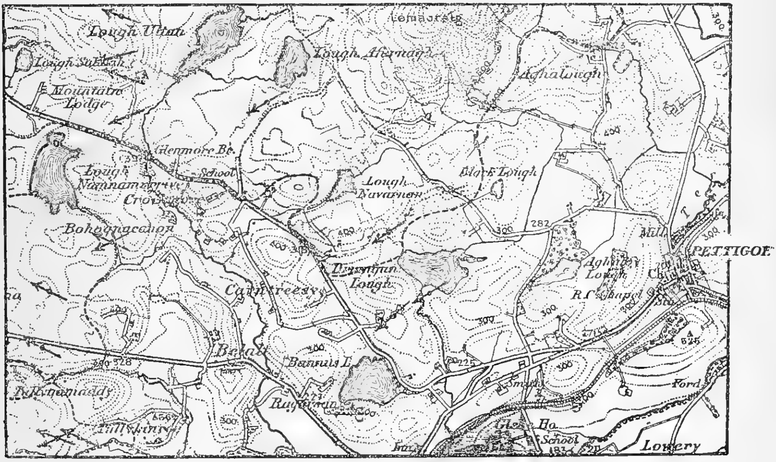


FIG. 2. Map of the district west of Pettigo, with contours every 25 feet to show the triangular and crescentic drumlins and the accompanying striæ indicating two directions of ice-motion. The heavy broken line marks the boundary of the Boulder-clay. Scale one mile to an inch. Reproduced with modifications from the Ordnance Survey Maps by permission of the Controller of H.M. Stationery Office.

Here the great majority of the drumlins are of hog-backed form and distinctly crested. An attempt is made in Fig. 3 to indicate the character of the country. The drumlin which stands out prominently in the centre of the picture is in every respect a perfect example of the class of hill which abounds in this district. Fig. 4 gives a more oblique view of the same class of drumlin. In both these sketches the undulating or serrated character of the crest is shown, and this is also well brought out in Pl. IX, Fig. 2. A curious feature is the intermixture of drumlins of other types. Thus Fig. 4 shows in the middle of the picture a small drumlin of the well known half-cigar

[1] See Vaughan Cornish, "On the Formation of Sand-dunes": Geogr. Journ., vol. ix, p. 290, 1897.

shape, without any marked crest and with an even unserrated profile. In the foreground on the right of Figs. 3 and 4 and also in the distance can be seen drumlins of gently domed outline without even a trace of a crest. Portion of the area depicted in Fig. 4 is shown as a contour map on the scale of 3 inches to a mile in Fig. 5. The drumlins numbered 1 to 5 in Fig. 4 bear corresponding numbers in the map. The contours, being at intervals of 25 feet, bring out the form of the ground with admirable precision. They show distinctly the narrowness of the crest and its serrated character, and make very apparent another peculiarity of certain of these drumlins, namely the forked outline at the downstream end. This forking is by no means a universal character, but a tendency to its development has been noticed in several parts of the Donegal and Ballintra area. Analogy with the crescentic drumlins to the west of Pettigo suggests that it is due to slight oscillation of the ice-motion.

Some cuttings on the Donegal and Ballyshannon Light Railway display very clearly the composition and structure of the drumlins of this area. The main mass of the hill is composed of stiff compact boulder-clay, but the upper 5 feet more or less is always relatively

FIG. 3. View of drumlin topography looking west from Trumman, one mile south of Laghy, co. Donegal. The drumlins are viewed from the upstream ends. Both rounded and crested types come within the field of view. Donegal Bay and St. John's Point are seen in the distance.

loose and loamy. The junction between this upper boulder-clay and the compact till is generally fairly well defined. Pl. IX, Fig. 3, shows the top of a railway-cutting through the end of one of the drumlins, in which the line between the upper and lower boulder-clay is marked by calcareous oozings due to the escape of water along the junction. It is not unlikely that the upper boulder-clay is englacial material let down on the surface during the decay of the ice, and so never compacted by the ice-motion.

On first visiting the Ballintra district I was under the impression that the crested nature of the drumlins might be due to landslipping, and I was encouraged in this belief by observing an obvious recent landslip on the slope of one of these drumlins near Rossnowlagh. Landslips, however, possess as a general rule well marked and easily recognizable features, and these I have not observed in connexion with any other drumlins in the district. Mr. Hallissy has suggested to me a much better explanation in soil creep, which would naturally be at a maximum on the steep side slopes, and almost negligible along the median line. Such action might in time lower the slopes and leave the median line standing up in the form of a crest. It is difficult to understand, however, how this process could produce a crest on one drumlin and leave another close by quite unaffected, as is often the case. I have therefore come to the conclusion that this feature is original and that the form of the drumlins is approximately the same as when they were first abandoned by the ice.

The mere occurrence of a crest gives ground for presuming that, in the building up of the drumlins, material is deposited mainly along the median line, and subsequently distributed down the slopes by the ice-motion. Its uneven serrated form is also in favour of this explanation as opposed to any process of ice-erosion or ice-moulding. The fact that crested and uncrested drumlins occur in the same area side by side is of considerable significance. It is explained by supposing that in the case of the crested drumlins deposition of material continued until the final exposure of the drumlin or until the ice became stagnant, while in the case of the uncrested drumlins deposition ceased before the ice came to rest, so that the subsequent ice-motion imparted a rounded outline to the top of the drumlin.

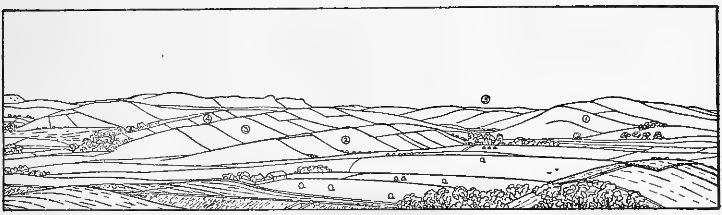


FIG. 4. View looking W.S.W. from a point one mile north of Ballintra showing several types of drumlin, the most numerous and typical having serrated crests. In the centre of the picture is a small drumlin of half-cigar form, and in the foreground on the right another of rounded form. Ben Bulben in the distance. The contours of the numbered drumlins are shown in Fig. 5.

Throughout the district examined there seems to be a well marked prevalence of drumlins of elongated ground-plan in areas where there is reason to suppose the fluctuation of ice-motion was least. It must be admitted, however, that the number of striæ recorded in these areas is not sufficiently great to prove the absence of variation in direction. It can, however, be very definitely stated that in the one area, that lying west of Pettigo, where a distinct oscillation has been proved, the drumlins assume shortly oval, rounded, triangular, and crescentic forms. The reason for this fluctuation is to be found in the existence of fairly lofty hills to the south of Lough Derg. During the later stages of the glaciation these formed a barrier to the ice coming from the north-east, so that the flows converging on the head of Lough Erne from the east and south-east obtained the upper hand. This consideration of the local conditions assures us therefore that in this area of conflicting striæ the north-westerly motion was later than the south-westerly. Moreover, there is a fair presumption that in the eastern part of this area the change in direction was less abrupt than in the western part which lies right in the lee of the hills. The eastern part has rounded drumlins, the western crescentic and triangular drumlins. It is suggested that gradual change of direction produces the rounded forms and sudden change the triangular and crescentic forms.

Further, there is a complete absence of cresting in this area of oscillation. The drumlins are smoothly domed and often subdued in profile. Change in the direction of the ice-motion seems to prevent the production or else the preservation of crests.

The ideas discussed above as arising out of the evidence cited may be summarized in the following propositions, which, however, are not regarded as proved, but are only put forward tentatively in order that their applicability to other areas may be tested.

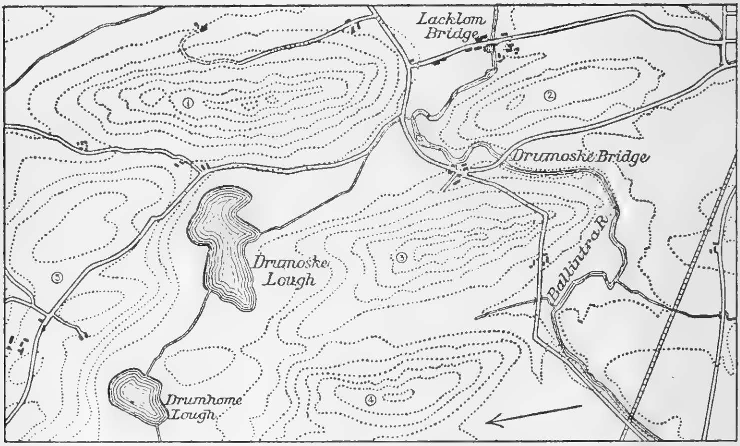


Fig. 5. Contour map of the drumlin topography west of Ballintra, co. Donegal. The drumlins, numbered 1 to 5, are marked with corresponding numbers in Fig. 4. Nos. 1, 3, and 4 are typically crested drumlins with serrated profile. They are also forked at the downstream end. No. 2 is of half-cigar form. Contours every 25 feet, taken from the Ordnance Survey Maps. Scale 3 inches = 1 mile. The arrow shows the direction of ice-motion. Reproduced by permission of the Controller of H.M. Stationery Office.

1. Drumlins are built up by the addition of material mainly along the median line.

2. If this addition of material is continued until the complete withdrawal of the ice or until the cessation of the ice-motion, then the drumlin is left with a crest.

3. If on the other hand the addition of material ceases before the ice-motion, then the latter imparts to the drumlin a smoothly rounded outline.

4. In areas where the ice-motion is constant in direction the resulting drumlins are elongated.

5. If on the other hand the direction of ice-motion is continually changing, the resulting drumlins are shortly oval.

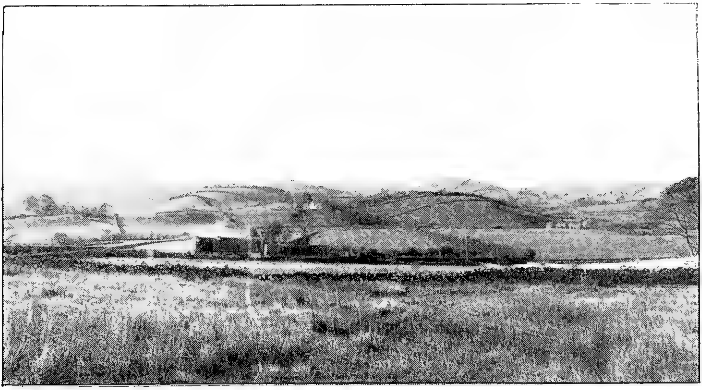


Fig. 1

Fig. 2

Fig. 3

Drumlins of South Donegal.

6. In cases where there is a relatively sudden change of motion the drumlins tend to assume triangular, crescentic, and forked outlines.

DESCRIPTION OF PLATES VIII AND IX.

PLATE VIII.

Sketch-map of South Donegal showing the glaciation. The drumlins, shown in black, are inserted to some extent from personal knowledge of the ground, but are also largely deduced from the contours of the 1 inch and 6 inch Ordnance Maps combined with the original drift-mapping of the Geological Survey of Ireland. The areas treated in more detail in other maps are outlined. At the point marked A there is a small latero-terminal moraine on the hillside. Scale ¼ inch to the mile. Reproduced with modifications by permission of the Controller of H.M. Stationery Office.

PLATE IX.

FIG. 1. View of drumlin topography from the Roman Catholic Chapel, Ballintra, looking west in the direction of the ice-motion.

FIG. 2. Drumlin with serrated crest viewed obliquely from the stoss end, Drumnacoil, near Bridgetown, one mile north of Ballintra.

FIG. 3. Railway-cutting near Rossnowlagh Station. Section through drumlin showing upper and lower boulder-clay. The line of junction is indicated by the calcareous oozings due to water percolating along the upper surface of the compact lower till.

IV.—THE BIRTH OF AN ISLAND NEAR THE COAST OF TRINIDAD.

By T. O. BOSWORTH, B.A., B.Sc., F.G.S.

AS some erroneous statements have appeared in the Press about this interesting event, it seems advisable that the true facts should be placed on record.

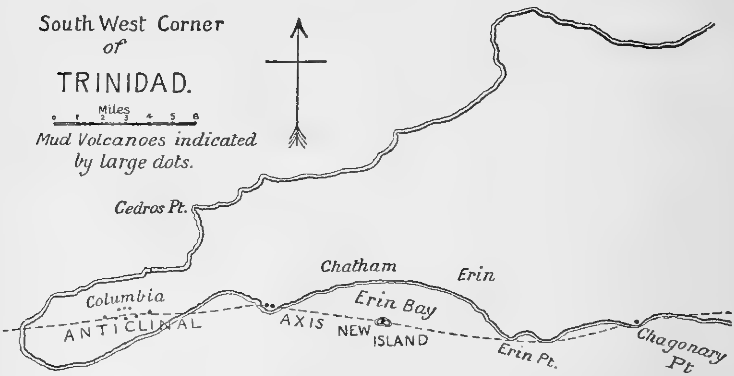
Geological Character of the District.

The shape of the Island of Trinidad is approximately rectangular and conforms to its simple geological structure. Along the north side is a mountain range formed of metamorphic rocks, but elsewhere folded Tertiary (and occasionally Cretaceous) strata are at the surface. The anticlinal axes are some two or three miles apart, and have parallel sinuous trends with a general east and west direction. They have been mapped over a large part of the island by Mr. E. H. Cunningham Craig, F.G.S., for the Government, and have been further mapped and studied in detail by the writer during the past year, some seven or eight distinct anticlines being now known. Some of these anticlines are found to die out in the course of a few miles, but two or three folds of greater importance are remarkably persistent, and one at least of these is now proved to be continuous from east to west right across the island and has been mapped throughout practically its whole length—a distance of over sixty miles. This anticline is nearly parallel with and close to the south coast of Trinidad, often being well exposed on the foreshore, but by reason of its sinuosities and the irregularities of the coastline the axis of the fold, though generally on dry land, is in some parts of its course under the sea. Indeed, where it crosses Erin Bay it must be nearly two miles from the shore. It is in this bay that the new island has been formed, directly on the line of the anticline.

The Tertiary strata of Trinidad consist of clays and lenticular, current-bedded sandstones, the whole sequence displaying remarkable lateral variation. Along the anticlines, which generally are sharp and very steep, petroleum has accumulated where the conditions are favourable, and its presence is manifested by escaping gas, seepages of oil, and by extensive surface spreads of pitch. In some places occur beds of clay-shale, which have become burnt (probably at depth) into red 'brick' by the spontaneous combustion of the hydrocarbons contained.

Neighbouring Mud Volcanoes.

Along the Southern Anticline 'mud volcanoes' are a characteristic feature. These are commonly cones of mud with a crater at the top from which issue gas, oil, salt water, and mud. The majority are only a few feet high, but some are much larger. Others again are but slightly conical, and appear as mud springs sometimes several hundred feet across. About forty mud volcanoes and groups of volcanoes are



known to the writer on this one anticline, and as a rule they are so truly situated on the crest that where rock exposures fail they have afforded invaluable evidence for mapping the anticline.

One of the largest of these volcanoes is at Chagonary Point, about 7½ miles east of the new island. Mr. Cunningham Craig says of it:[1] "The circular area of barren mud marking the crater is some 80 yards across, and a flow of mud has descended to the beach a distance of 250 yards. Trees one foot in diameter have been broken and the upper part thrown away from the centre of the outburst. Blocks of rocks up to 15 inches in diameter have been brought up from beneath the surface and scattered about the mud crater. They consist of ironstone nodules, nodules and crystalline groups of pyrites, Cretaceous pebbles, coarse Tertiary grit, and fine pale sandstone with plant remains and calcite vein-stuff. A bituminous odour is noticed on all the porous ejected fragments and in fact a smell of petroleum pervades the whole locality."

Another large one is the Columbia volcano near Cedros, about ten

[1] Council paper No. 119, Trinidad, 1905.

miles west of the new island, which has been described by Mr. A. Beeby Thompson, M.I.Mech.E., F.G.S.,[1] as follows:—"Several acres of ground were quite bare of vegetation and strewn with newly ejected argillaceous mud mixed with occasional fragments of iron pyrites, etc. All over the area inflammable gas was oozing up through numberless fissures with a hissing sound, and towards the centre was a crater of stiff pasty clay kept in agitation and puddled by the evolution of immense volumes of gas. This central crater had a diameter of about 60 to 80 feet, and the discharged mud was so soft around that close approach was unsafe. At intervals of a few minutes violent eruptions occurred, accompanied by the evolution of enormous volumes of gas, causing the ejection of many tons of clay to a height of 20 to 30 feet. Before each explosion the ground for a radius of 50 feet heaved and quivered, and the central portion rose slowly until it burst, causing the expulsion of masses of clay, the bulk of which fell back into the crater in great blocks."

The New Island.

The writer left the locality about three months before the birth of the new island, and the following account of it is from a letter written by Mr. E. C. Buck, A.M.I.C.E., A.M.I.M.E.:—

"At 5.30 p.m. on the 4th inst., at a point between Chatham and Erin and about 1½ miles to sea, a tremendous explosion took place accompanied by an enormous column of fire, and mud and stones were thrown out to such an extent that an island having an area of about 2½ acres was formed in a few minutes. The highest portion of the island is about 14 feet above high water level.

"On the morning of the 5th inst. the Governor rang me up and asked me to go with him to discover this island. We started at 8.30 a.m. and sighted the island at 4 p.m. From my observations I find that the island is situated at a point 1¾ miles from Chatham and 3½ miles from Erin, and on a line passing through Points Islot and Erin. I had the pleasure of being the first to land, and it was a rather risky proceeding as the mud and clay was still very pulpy and under the crust the mud was exceedingly hot. However, I effected a landing and the others soon followed. Two craters were discovered near the northern end of the island, one being very active in ejecting. The shape of the island is an ellipse with the major axis running north-west to south-east. I obtained some good examples of the strata thrown up."

"By chance the explosion was observed by Mr. A. C. Veatch, a geologist, who was on board ship some miles away. His notice was suddenly attracted by a great flame that shot up into the sky at dusk. With the first puff the flame rose as a brilliant mushroom-shaped mass, which immediately changed its form to a straight jet of fire that must have risen to a height of at least a thousand feet. No noise whatever, preceding or accompanying the fire, was heard by this observer, who was fourteen miles away. The fire disappeared below the horizon in about five minutes, leaving a cloud of smoke that drifted away."[2]

[1] *Petroleum Mining*, 1910. [2] From the *Morning Post*, January 5, 1912.

And in another letter from Mr. E. C. Buck, dated January 22, 1912: "A sandy beach of considerable extent has now formed round the island, and the craters have diminished to the ordinary dimensions of the mud volcanoes on land."

The specimens have been examined by Mr. Beeby Thompson, sen., F.C.S., F.G.S., and by the writer.

The main bulk of the erupted material is bluish clay mud with an oily smell and quite similar to that produced by neighbouring mud volcanoes.

The rock fragments consist of sandstone, clay-shale, burnt clay, pyrites, etc. The burnt clay is a hard red 'brick' like that occurring in other localities as mentioned above, but as no bed of such rock is found near here it seems probable that the burning has been performed during this eruption.

The pyrites is in bright crystals and some of the rock fragments are highly charged with it. There are also aggregations of it forming nuggets several inches across. This mineral is often conspicuous in the ejecta of mud volcanoes, and is interesting in view of the common association of sulphurous waters with petroleum and the frequent presence of sulphur in the oil.

From the crater were taken some fragments of a fine argillaceous breccia. It is calcareous and contains, besides pyrites, some small shells and Foraminifera. This rock was analysed by Mr. Beeby Thompson, who found in the matrix a high proportion of calcium phosphate and ferrous carbonate. It is in fact a kind of clay ironstone. At the surface no exposure of this bed has been observed.

It is probable that previous eruptions have occurred on the site of the new island, for it is apparently coincident with a mound on the sea-floor which is shown on the Admiralty charts. Soundings have proved a depth of only 1 fathom at this spot, though it was surrounded by water 3 fathoms deep.

The facts which have been described above can leave little room for doubt as to the origin of the new island.

Analogous Events in Borneo and Burma.

Two similar instances may be cited for comparison which are described by Mr. A. Beeby Thompson in his work on *Petroleum Mining*—[1]

"On 21st December, 1897, the disturbance occasioned by an earthquake led to the formation of a great mud volcano beneath the sea off the southern point of the Klias Peninsula of Borneo, when sufficient argillaceous material was ejected to form a new island 750 feet long, 420 feet wide, and 20 feet above sea-level. The eruption occurred on the crest of a well-known anticline with steep sides, on which petroleum gas exudations had frequently been observed in other localities, where it crossed the land.

"Probably one of the greatest mud volcanoes on record was formed off the Burma coast on 15th December, 1907, when sufficient material was ejected to form an island 1,200 feet long, 600 feet wide, and

[1] *Petroleum Mining*, 1910, pp. 102–3.

20 feet above sea-level, upon which a landing was effected by the officers of a British marine survey ship shortly after the eruption, when the mud still indicated a temperature of 148 deg. Fahr. a few feet below the surface."

V.—A Note on the Carboniferous Limestone of the Crich Inlier.

By H. C. Sargent, F.G.S.

I CHANCED a few weeks ago to see, for the first time, a short paper by Mr. J. Wilfrid Jackson, F.G.S., in the Geological Magazine (Dec. V, Vol. V, p. 266) on "Mottled Foraminiferous Limestone in West and North Lancashire". In that paper Mr. Jackson thus describes specimens of mottled limestone from Silverdale: "The matrix is light-coloured and fine-grained, with irregularly shaped patches (? nodules) of a fine-grained dark-coloured limestone. The patches have no definite shape, being mostly very uneven in size, some of them being long cylindrical bodies with irregular contours."

Mr. Jackson writes with special reference to a paper by Messrs. Barnes & Holroyd, in which they describe limestone of the same character from North Derbyshire,[1] and similar mottled beds may also be seen in the quarries near Crich in the southern part of the county.

Messrs. Barnes & Holroyd, in the paper referred to, show, as I think, conclusively that the difference in colour between the dark and light portions is due to a larger proportion of carbonaceous matter in the former than in the latter. They go on, however, to say that this "is caused by the absence in the light part of the remains of foraminiferal life, while in the dark we have abundant life remains, and these in a most perfect state of preservation". On this point Mr. Jackson states as follows: "In the Silverdale specimens, so far as I have made out, foraminifera are almost as numerous in the light portion of the rock as in the dark,"[2] and this observation agrees with my own examination of thin slices prepared from the Crich rock.

Messrs. Barnes & Holroyd are further of opinion "that the dark and light are not the same limestone, but that the dark has been removed from its original place of deposition and intermingled and cemented into the lighter matrix".[3] They consider that this process has been effected by volcanic activity. "Given that these outbursts of volcanic activity were preceded by the usual earth shocks and sea disturbances, and the neighbouring presence of calcareous beds of dark foraminiferal mud, we have all the conditions necessary for the turning up from the sea bottom, and consequent removal to another area of the dark parts, together with the redeposition and consolidation to produce the peculiar mottlings."[4] Whereupon Mr. Jackson naturally inquires whether these effects of volcanic activity in

[1] "On the Mottled Carboniferous Limestone of Derbyshire": Trans. Manch. Geol. Soc., vol. xxvi, p. 561.

[2] Loc. cit. [3] Loc. cit. [4] Ibid.

Derbyshire were felt "so far away as Grange and Silverdale". I venture to think that the presence of this dark limestone in a lighter matrix may be explained in a much simpler way.

In the Crich area we have limestone of every shade of colour from white, through grey, light blue and dark blue, to black. There is generally a clear line of demarcation between each shade of colour, and this frequently takes the form of an impervious clay-band. The mottled beds are also present, and they invariably, so far as my observation goes, form passage beds between lighter and darker shades of the rock in places where there are no clay-bands to delimit the areas of the two shades. These mottled beds are called 'curly' by the quarrymen, in allusion to their somewhat irregular fracture, which frequently follows the boundary-lines of the dark patches, as Messrs. Barnes & Holroyd state in their paper.

In Hilt's Quarry, Crich, where the mottled beds may best be studied, they occur on two horizons: (1) between beds of white and light-blue limestone, (2) between beds of light-blue and dark-blue limestone. In each case the two shades of the mottled or 'curly' rock are the same as those of the rock above and below respectively.

There can therefore, I think, be no doubt that the dark and the light of the mottled rock are the same limestone; in other words, that they were deposited contemporaneously.

The varying shades of colour in the limestone are due to varying proportions of carbonaceous or bituminous matter contained in it. The percentage of such matter in specimens collected in Hilt's Quarry ranges from 0·62 in the white to 2·02 in the black. (Analyses by Mr. Eric Sinkinson.)

The presence of this carbonaceous or bituminous matter in the limestone is difficult to explain satisfactorily in all circumstances, especially in view of its frequent impersistence horizontally. The matter is still under investigation, and I hope to have more to say about it before long. At present it seems probable that it may be of both original and secondary origin—original in regard to organisms embedded during deposition, secondary as the result of subsequent infiltration. Possibly the latter has had the wider effect.

Finally, I suggest that if the supply, whatever be its source, were insufficient to permeate fully the rock accessible to its influence, there would be a tendency, owing to the nature of the substance, for it to collect into oleaginous patches, of shape and size varying according to the supply available and the conditions of environment, such as capillary influences, degree of porosity, etc. This I believe to be the explanation of the mottled or 'curly' rock.

VI.—The occurrence of a Human Skeleton in Glacial Deposits at Ipswich.

By George Slater, F.G.S.

The great interest excited by the recent announcement in the *Times* and elsewhere of the alleged discovery of a skeleton of "pre-Boulder-clay man" renders it desirable that the geological evidence should be carefully examined.

At a meeting of the Prehistoric Society of East Anglia, held at Ipswich, February 21, 1912, Mr. J. Reid Moir read a paper on "The occurrence of a Human Skeleton in a Glacial Deposit at Ipswich". The sand-pit from which the bones were obtained is worked by Messrs. Bolton & Laughlin, brickmakers, and is situated about a mile north of Ipswich, and west of the Henley Road near the Prospect Cottages. The bones were discovered on Friday, October 6, 1911, whilst workmen were engaged in removing some surface clay near the top of the eastern side of the pit in order to get at the underlying sand and gravel. The general section on this side of the pit is extremely unsatisfactory. Capping a considerable thickness of sand and gravel (the latter in places containing derived Jurassic material in the upper parts) is a bed of extremely weathered clay not more than 4 feet in maximum thickness including the top soil and turf, but only 2 feet thick in the sides of the trench where the bones were discovered, and of this 1 foot can only be described as soil. It is important to remember that the Boulder-clay thins off entirely near this point to the south-east, this fact being well shown on a geological map of the district recently made by Mr. P. G. H. Boswell, B.Sc., F.G.S., and Mr. I. Double, of Ipswich, the 6 inch ordnance maps of the district being used for the purpose.

The weathering of the clay has gone on to such an extent that only small scattered patches of unweathered chalky Boulder-clay occur. The decalcified clay is of a deep-brown colour, and is crowded with roots which often pass quite through the clay into the sands below. The result of this is that the free passage of water through the clay is easy and consequently infiltration has been excessive. Below the clay the underlying sands are deeply stained with iron oxide in places to over 1 foot, and beneath the stained portion is a fairly constant calcareous band.

It was only after the bones had been entirely removed to London that Mr. W. Whitaker, F.R.S., Dr. Marr, F.R.S., and myself were asked to report on the beds in the section and in the sides of the empty trench.

Mr. Whitaker, in the course of his report, said: "The pit is worked for sand and gravel, belonging to the glacial drift, and is just where Boulder-clay is marked on the geological survey map as coming above the sand. There is no doubt in my mind that the pit gives a junction-section of the Boulder-clay with the underlying sand and gravel. The skeleton was found at the eastern side of the pit at this junction. *The top earth was only some 3 feet thick,* and the process of weathering has gone to such an extent that perhaps no one seeing merely that one particular spot would say that Boulder-clay occurred, but there is unweathered Boulder-clay close by in the same sandy or loamy earth, and I can see no reason to differentiate one particular yard or so from its surroundings. I could see no signs of artificial disturbance of the soil, and was told that none had been seen during the excavation. Slipping seems out of the question." Referring to the fact that the bony cavity of the skull is filled with earth of *the same kind as that in which the skeleton was found,* he said: "I fail to understand how man could have lived at the time of the commencement of the Boulder-clay, and I am in hopes that further excavation may throw more light on this strange occurrence."

Dr. John E. Marr, who visited the site after the skeleton was removed, reported that the clay resembled decalcified Boulder-clay, and had patches of unaltered clay here and there. It was very thin, and *he hesitated to pronounce any definite opinion.* He did not know how one would distinguish between Boulder-clay in situ and clay which had been derived from Boulder-clay at a somewhat higher level, which had flowed as the result of being waterlogged. Such flows were often seen on beaches below Boulder-clay cliffs, and they strongly resembled true Boulder-clay. He did not, however, suggest that the clay above the skeleton had that origin, but that personally he was unable to distinguish a thin mass of such a clay from true Boulder-clay. In the course of a further letter on the subject Dr. Marr said that he could see no difference between the decalcified Boulder-clay in the higher pit above the normal undecalcified Boulder-clay, and the decalcified clay above the skeleton. The slopes in the vicinity were very slight, but they might have been diminished by erosion, and it was possible that the clay might have been moved from another place.

According to the report in the *Times* the skull was filled with Boulder-clay. During the lecture Professor Keith referred to this point. With regard to the skull having becomed filled, Professor Keith remarked, that the material, which was *the same as the stratum in which the skull lay*, could only have been carried in by three agencies—water, roots, and worms—and he thought the last two might be excluded. They were driven to suppose that, when the skull came to rest, there existed a more moist or fluid condition of the stratum.

It will be seen from these reports that neither Mr. Whitaker nor Dr. Marr can be looked upon as very decided supporters of Mr. Moir's view. The very important point raised by Dr. Marr as to the effect of the slopes on erosion is crucial to the present matter. Both Mr. A. D. Hall, M.A., F.R.S., and Dr. Russell have shown in their investigations on soils that even a sedentary soil is never at rest, and that rain-wash is an important factor in soils even when the slopes are slight. In the present case the site of the discovery is on the side of a valley. The plateau to the east reaches a height of about 160 feet, half a mile to the east of the section; this gives a gradient of roughly fifty feet in half a mile. Between the plateau to the east and Norwich Road on the west, a distance of one mile, there is a drop of 100 feet or more. It is quite reasonable to conclude that the upper part at least of the clay in the section is the result of slow accumulations of rain-wash.

The calcareous band referred to in the sands beneath the clay is in the nature of a 'cemented pan', the rainfall being only sufficient to remove the calcareous matter from the clay down to a depth of three or four feet. Certainly such a bed is no sign of antiquity as such 'pans' are known to form quite rapidly. It is obvious that everything depends upon the evidence of those who saw the bones in situ.

Mr. Moir was informed of the discovery and his account of the excavation is interesting. He at once went down to the pit where the discovery had been made, and found that a portion of a human skull attached to an almost complete cranial cast, had been recovered. The workmen pointed out that two bones were protruding from the spot where the skull had been derived, and *said it was arranged for the remainder of the skeleton to be dug up on the following day.* Recognizing the importance of having the disinterment properly and carefully observed, three gentlemen—Messrs. Woolnough, Canton, and Snell—accompanied him, and they afterwards drew up a short report of their observations. In this report of the digging out *on October* 7, they say:—"We all most carefully examined the section of decalcified Boulder-clay, *under which the bones lay*, before any digging commenced, and we are absolutely convinced that *no grave* had ever been dug on the spot before. This opinion was confirmed (1) by the *extreme hardness* of the *Boulder-clay*, which necessitated the continued use of picks in getting it up. (2) There was not the slightest sign of any mixing of the soils (such as would occur in an old grave), the Boulder-clay *resting normally on* the underlying glacial sand as it does in all sections known to us where the succession of the beds is the same. (3) That in the event of a grave having been dug in the past on this spot, it is hardly conceivable that we should have dug down in exactly the same place as the original diggers, and that therefore one side at least of their digging would be visible in the remaining section of Boulder-clay.[1] (4) *The extraordinary cast of decalcified Boulder-clay*, which completely filled the inside of the skull, we consider points to the conclusion that the clay was in a semi-fluid state at or since the time when the remains were embedded in it. We think it most unlikely that the clay in its present hard condition (a condition which has apparently been present since the last great extension of the glaciers) could work its way into any skull buried in it. (5) *The bones were lying partly embedded in glacial sand and partly in decalcified clay*. This sand showed most plainly the lines of stratification, and was quite conformable with that underlying it."

The report of these gentlemen says: "We all most carefully examined the section of decalcified Boulder-clay, *under which the bones lay* . . ." And yet in (5) "the bones were lying *partly embedded in glacial sand and partly in decalcified clay*".

During the lecture Professor Keith also referred to the same point. The right side of the skeleton, which lay in contact with the glacial sands, was much better preserved than the left, which was uppermost, and *embedded in the Boulder-clay*, and thus most subjected to the destructive effects of the roots of plants and the eroding action of the clay. The roots reached deeply in the glacial sands, and their effects were absolutely manifest on the skull and pelvis. The Boulder-clay (sandy, chalky loam) had also eaten into the bones, and all the soft spongy bone (feet, spine, etc.) was represented by dense clay in which minute fragments of the original bone could be detected. Thus, there was not a single complete bone recovered with the exception of the small bones of the right hand. By great

[1] See letter by Professor T. McKenny Hughes, F.R.S., on "Obliteration of Traces of Interment" (*infra*, p. 187).

good fortune the cavity of the skull must have been completely *filled at an early stage with the surrounding matrix*, and thus a complete cast of its interior had been preserved. A fragment of the frontal bone, sufficient to show the characters of the forehead, parts of both temporal bones, with the joints of the mandible and fragments of the parietal and occipital bones, were also present. The face and jaws were gone, but fortunately nine of the teeth were found.

At the close of the meeting, in answer to a question, the point was again referred to. Dr. Hossack pointed to the fact that many of the bones, not only soft ones, but others, had disappeared, but Professor Keith replied that this was *due to the position of the skeleton in the clay and sand*, the bones preserved being chiefly those from the sand.

The evidence as to the position of the bones seems to be unmistakable, they were found partly in the Boulder-clay and partly in the sand. It is difficult to understand how this could have occurred naturally under any circumstances. The sand was presumably deposited by running water, the Boulder-clay by moving ice, entirely different conditions obtaining at different times.

As to the theory that these remains may have been buried, Professor Keith remarked there were various pebbles and splinters of stone found immediately beneath certain parts of the skeleton, as if they might have rolled into the open grave, but in the deepest stratum of the Boulder-clay such stones were abundant and the question of burial must be left open. With regard to the signs of antiquity in the bones, he pointed out that the bones were not mineralized, but, on the contrary, were extremely light. The bony matter had exactly the appearance of chalk.

Much stress has been laid on the fact that those who saw the bones in situ saw no indication of a grave.[1] But we should not expect to see such indications considering the time which has probably elapsed since the death of the person whose skeleton was found. There is much general evidence on this point. Even comparatively recent graves, as seen at the cliffs near Dunwich, are difficult to trace.

In the Journal of the Suffolk Institute of Archæology, 1907, Miss Layard, F.L.S., in describing an Anglo-Saxon Cemetery, Hadleigh Road, Ipswich, presumably a Pagan cemetery of the sixth century (p. 6), says (p. 1): "On a first visit to the spot in January, 1906, I noticed human bones protruding from the side of the cutting, but as the skeleton had already partly been removed, nothing was found with it. The clean condition of the red crag in which the bones lay was sufficient proof that the burials were of very early date, as there was little trace of organic discolouration in the surrounding earth." The depth of these graves seems to have varied from about 2 to 4 feet, and apparently the only indications of graves were to be seen in the presence of bones and ornaments. In the present instance the bones were found about 3 feet below the surface.

All the evidence points to the probability that the man was buried in a narrow shallow grave, but there is no evidence as to when this took place; we can only label the skeleton "of doubtful age".

[1] See Professor T. McKenny Hughes' letter (*infra*, p. 187).

NOTICES OF MEMOIRS.

On the Fossil Flora of the Forest of Dean Coalfield (Gloucestershire), and the Relationships of the Coalfields of the West of England and South Wales. By E. A. Newell Arber, M.A., Sc.D., F.G.S., University Demonstrator in Palæobotany, Cambridge.

Reprinted from Proc. Roy. Soc. London, B 579, vol. 84, p. 543, 1912.

VERY little has been previously recorded of the flora of the Forest of Dean Coalfield, and in the present paper the results of a thorough examination of the flora, and of the vertical distribution of the plants in the three divisions of the productive measures of this coalfield, are discussed. In all forty-four species are described, none of which, however, are new to Britain, though some are rare plants elsewhere. The list of species is as follows:—

EQUISETALES.

Calamites varians, Sternb.; *C. ramosus*, Artis; *C. suckowi*, Brongn.; *C. undulatus* (?), Sternb.
Calamocladus equisetiformis (Schloth.).
Annularia radiata (?) (Brongn.); *A. stellata* (Schloth.); *A. galioides* (L. and H.); *A. sphenophylloides* (Zenker).
Calamostachys tuberculata (Sternb.).
Macrostachya infundibuliformis (Brongn.).

SPHENOPHYLLALES.

Sphenophyllum emarginatum, Brongn.; *S. majus* (Bronn).

PTERIDOSPERMEÆ AND FILICALES.

Sphenopteris neuropteroides (Boulay); *S.* (*Renaultia*) *chærophylloides* (Brongn.).
Mariopteris muricata (Schloth.); *M. latifolia* (?) (Brongn.).
Neuropteris scheuchzeri, Hoffm.; *N. macrophylla*, Brongn.; *N. ovata*, Hoffm.; *N. rarinervis*, Bunb.; *N.* (*Cyclopteris*) *fimbriata*, Lesq.
Alethopteris aquilina (Schloth.); *A. grandini* (Brongn.); *A. davreuxi* (Brongn.).
Pecopteris miltoni (Artis); *P. polymorpha*, Brongn.; *P. arborescens* (?) (Schloth.); *P.* (*Dactylotheca*) *plumosa* (Artis).

SEMINA INCERTÆ SEDIS.

Trigonocarpus noeggerathi (Sternb.).

LYCOPODIALES.

Lepidodendron lanceolatum, Lesq.; *L. aculeatum*, Sternb.; *L. wortheni*, Lesq.; *L. dichotomum*, Sternb.
Lepidophloios cf. *L. laricinus*, Sternb.
Lepidophyllum majus, Brongn.; *L. brevifolium*, Lesq.
Sigillaria lævigata, Brongn.; *S. elongata*, Brongn.; *S. rugosa*, Brongn.; *S. trigona*, Sternb.; *S. tessellata* (Sternb.); *S. brardi*, Brongn., var. *denudata* (Goepp.).

CORDAITALES.

Cordaites angulosostriatus, Grand'Eury.

The floras of the three divisions of the productive measures in the Forest of Dean are compared, and it is found that they are practically identical. All three divisions belong to the palæobotanical horizon known as the Upper Coal Measures. It is shown that there is a marked agreement between the flora of the Forest of Dean and the Upper Coal

Measure floras of other British coalfields, though the following species which occur in the Forest have not previously been recorded from this horizon elsewhere :—

Annularia galioides (L. & H.).
Sphenophyllum majus (Bronn).
Mariopteris latifolia (?) (Brongn.).
Lepidodendron dichotomum, Sternb.
Sigillaria rugosa, Brongn.; *S. trigona*, Sternb.; *S. brardi*, Brongn., var. *denudata* (Goepp.).

The flora of the Forest of Dean is contrasted with those of the neighbouring coalfields. As compared with the Radstock flora, there is found to be a general agreement, though there are important differences in detail, which are more marked than those which exist between the known floras of Radstock and Bristol. These differences, however, do not appear to indicate any considerable disagreement as regards the horizon, for the percentage of Stephanian plants present is approximately the same in each case. They are best explained as local variations in the distribution of the flora of the period.

The horizon of the so-called Millstone Grits, below the Upper Coal Measures and above the Carboniferous Limestone, is discussed. Reasons are advanced in support of the view that the Upper Coal Measures of the Forest overlie unconformably the so-called Millstone Grits, which in reality are the higher beds of the Carboniferous Limestone Series, which here have an arenaceous facies. True Millstone Grits, as well as Lower, Middle, and Transition Coal Measures, are absent in the Forest of Dean.

The relationships of this coalfield to the neighbouring coalfields of the West of England and South Wales are discussed from the palæobotanical standpoint. It is found that the Forest of Dean basin exhibits no obvious relationship, either to the South Wales or to the Radstock–Bristol coalfields.

The Pennant Grits of South Wales belong to a lower horizon than the markedly arenaceous series (the 'Forest of Dean Stone') of the third division of the Forest. The Radstock–Bristol and Forest of Dean basins are believed to be related tectonically, though not to the main axes of South Wales and the Mendips, but to a secondary cognate uplift, stretching north and south, and approximating to the valley of the Severn. On the other hand, the Forest of Dean does not appear to be related to the Welsh borderland series of coalfields, stretching from Newent to Shrewsbury.

In the case of the Forest of Dean it seems evident that the Lower Carboniferous rocks and the Old Red Sandstones of the area remained elevated above sea-level, and were denuded until the beginning of Upper Coal Measure times, whereas in South Wales depression and deposition set in in Middle Coal Measure times, and in the Radstock-Bristol area during the Transition Coal Measure period. Thus, on the palæobotanical evidence, the relationships of the coalfields of the West of England and South Wales have proved to be more complex than has hitherto been supposed, and this appears to be due, in part at least, to the coincidence of three distinct axes of elevation in the neighbourhood of the Forest of Dean.

REVIEWS.

I.—Géologie du Bassin de Paris. Par M. Paul Lemoine. 8vo; pp. ii, 408, with 9 plates and 136 text-illustrations. Paris, Hermann & Fils; London, Dulau & Co., 1911. Price 15 fr.

(*Second notice, continued from p. 136.*)

The Portlandian strata comprise, in the upper part, estuarine deposits and fluvio-lacustrine beds with fossils that would connect them with our Purbeck Beds. These latter, however, are not separately recognized, being regarded as the upper part of the Portlandian.

The Lower Cretaceous formations commence with the Aquilonian and Wealdian, which represent the continental facies of the Neocomian. The Aquilonian consists of clays, sands, and iron-ore, in general not fossiliferous. In the Boulonnais there appears in places to be a passage from Portlandian to Aquilonian, but as a rule there is great discordance.

In the Paris Basin the following divisions in descending order are made:—

CRETACEOUS.

Montian Danian		grouped together as 'Calcaire pisolitique'.	
Senonian:	Zones	*Belemnitella mucronata* *B. quadrata*	Aturian.
		Micraster cor-anguinum *M. decipiens* [1]	Emscherian.
Turonian:	Zones	*Holaster planus.* *Inoceramus labiatus.* *Belemnites (Actinocamax) planus.*	
Cenomanian:	Zones	*Schloenbachia varians* and *Acanthoceras rotomagense.* *Scaphites æqualis.*	
Albian:	Zones	*Schloenbachia inflata.* *Hoplites interruptus.* *Douvilleiceras mamillare.*	
Aptian:	Zones	*Exogyra sinuata.* *Terebratella Astieriana.*	
Barremian:		Argiles bigarrées.	
Neocomian:		Calcaire à Spatangues (facies marin). Aquilonian and Wealdian (facies continental).	

This grouping (apart from zones) is the same as that given in the British Museum *Guide to the Fossil Mammals and Birds* (1909).

The Neocomian consists of marine beds (*calcaire à Spatangues*) and lacustrine strata, which include those of Bernissart in Belgium, with *Iguanodon.*

The Barremian also includes both marine and lacustrine strata, mottled clays and sands, and oolitic iron-ore, with *Ostrea Leymeriei* in the lower part, and *Unio*, *Paludina*, etc., above.

The Aptian, characterized by green (glauconitic) sands, overlaps preceding deposits and rests on different Jurassic formations, as in the Ardennes.

The Albian comprises, at the base, green (glauconitic) sands with

[1] *M. cor-testudinarium* auct.

phosphatic nodules of considerable economic importance; the higher strata consist of clays and alternations of sands, marls, and clays (*argiles du Gault*). The Albian reposes on different formations from older Cretaceous to various Jurassic divisions.

In the Cenomanian further overlap took place, and it rests in places directly on the Palæozoic.

Remarks are made on the difficulty in fixing divisions in the Chalk of the Paris Basin, not merely on account of lithological changes, but owing apparently to the presence of similar species of fossils at different levels.

The Cenomanian consists in places of glauconitic sands with *Pecten asper* (found also in Albian), and with phosphatic nodules worked in Marne. Higher beds consist of grey marls and marly limestones with *Holaster subglobosus* and *Acanthoceras rotomagense*. The passage-beds between Cenomanian and Turonian are formed by the white and nodular marl with *Belemnites plenus*. *Rhynchonella Cuvieri* occurs in the higher part of the Lower Turonian, and *Inoceramus labiatus* is found (rarely) in the Upper Turonian with the so-called *Terebratulina gracilis*; higher up in the series *Holaster planus* and *Micraster breviporus* are met with. *Marsupites ornatus* is recorded from the highest part of the Emscherian, and *Bourgueticrinus ellipticus* from the base of the Aturian, which contains both *Belemnitella mucronata* and *B. quadrata*. A full account, with analyses, is given of the phosphatic chalk worked in the zone of *B. quadrata* in Picardy.

It is remarked that chalky conditions continued to exist in northern regions, and notably in Belgium, after they had ceased in France, where no representatives of the Chalk of Spiennes and Ciply are met with. The Chalk of Meudon and Epernay, with *Micraster Brongniarti* and *Ostrea vesicularis*, is grouped with the Aturian or uppermost part of the Senonian. With regard to the Montian division it is stated, on the authority of Munier-Chalmas, that the lower portion is characterized by Senonian and Danian forms of life; the upper portion contains the typical Montian fauna. This fauna, of an age between Cretaceous and Tertiary, includes *Nautilus danicus*, large forms of *Cerithium*, *Cidaris Tombecki*, *C. distincta*, etc. The deposits have been termed 'Calcaire pisolitique',[1] but the grains were due to calcareous algæ. Towards the upper part of the Chalk of Meudon there are indications of the roots of plants beneath the pisolitic bed. Evidence of overlap of this higher bed are noted; it rests on the Emscherian Chalk in the valley of the Mauldre, Montainville.

Some remarks are made on the Clay-with-flints (*Argile à Silex*), which is of different ages, in part post-Pliocene.

The nomenclature adopted for the ages of the Tertiary formations is as follows:—

PLIOCENE.

SICILIAN	Sables de St. Prest.
PLAISANCIAN	Couches du Boscq d'Aubigny.
PONTIAN	Couches à *Cardita striatissima*.
SARMATIAN	Conglomérat de Gourbesville.

[1] In the table, p. 132, both Danian and Montian are grouped as 'Calcaire pisolitique', and placed above the Senonian.

MIOCENE.	
TORTONIAN	Faluns de l'Anjou. Faluns de Touraine.
HELVETIAN	Sables de Sologne.
BURDIGALIAN	Sables de l'Orleanais.
AQUITANIAN	Calcaires de l'Orleanais.
OLIGOCENE.	
CHATTIAN	Meulières de Montmorency.
STAMPIAN	Sables de Fontainebleau.
SANNOISIAN	Calcaire de Brie.
EOCENE.	
LUDIAN	Etage du gypse.
BARTONIAN	Sables de Marine: Calcaire de St. Ouen.
ERMENONVILLIAN	Sables de Beauchamp.
LUTETIAN	Calcaire grossier.
YPRESIAN	Sables de Cuise.
SPARNACIAN	Argile plastique.
THANETIAN	Sables de Bracheux.

In this table there is agreement in the subdivision of the Miocene with the series adopted in the British Museum Guide (beforementioned): elsewhere harmony does not prevail. M. Lemoine gives a tabular statement to show the classifications adopted by different geologists, but it does not give all groupings such as those of Renevier (1897). It is desirable that some system of nomenclature be generally adopted, although none can be perfect. The stratigraphical divisions that would be represented on a geological map vary from place to place, and they have an independent practical as well as scientific importance. Chronological divisions should be based on localities where the fauna and flora are well represented.

The Quaternary deposits are grouped as follows:—

RECENT (Actuel)		Period of Metals. Neolithic.
PLEISTOCENE	Upper:	Epoch of Reindeer. Magdalenian.
	Middle:	Epoch of Mammoth with *Rhinoceros tichorhinus*, etc. Moustierian.
	Lower:	Epoch of Hippopotamus with *Elephas antiquus*, etc. Chellean (first indisputable remains of Man in Europe).

The latest stage of the Pliocene is noted as the epoch of *Elephas meridionalis*, with *Rhinoceros etruscus* and *Equus stenonis*; and it is bracketed, with a query, under Palæolithic.

The concluding chapters of this work deal with geomorphology and give a general summary of results. There is a copious bibliography, but it contains no reference to any of Prestwich's works. There are good indexes of species and localities, and a full table of contents.

II.—WIMBLEDON COMMON: ITS GEOLOGY, ANTIQUITIES, AND NATURAL HISTORY. By WALTER JOHNSON, F.G.S. 8vo; pp. 306, 9 plates, 3 maps, text-illustrations. London: Fisher Unwin. February, 1912. Price 5*s*. net.

TO all London dwellers who are lovers of natural history, of prehistoric archæology, and of that later history which lends so much romance to "the grandest of our suburban open spaces", this book should prove a delightful companion. But readers of this Magazine in particular will be glad to learn that fully one-third of the book is devoted to the geology and physical geography of the Common. This is probably the best part of the book, and, together with the chapter on the Common in prehistoric times, bears witness to the most intimate personal knowledge and study. There are various geological problems connected with Wimbledon Common, but the most important of these and the most difficult to solve is the age of the large sheet of gravel to which it owes its existence. After discussing the various theories with full reference to other parts of the Thames Valley, and after describing in detail the various sections to be seen on or near the Common itself, Mr. Johnson concludes that "the precise age of the gravels must frankly be left undecided. That they are river-gravels belonging to a date anterior to the formation of the Second or 100-foot Terrace may be considered certain", and Mr. Johnson is inclined to think that they are of slightly earlier origin than those of Dartford Heath, and that they were deposited contemporaneously with the Boulder Clay or possibly earlier. Shortly afterwards the plateau was raised, never again to be covered by water. This view agrees in the main with that of Messrs. Hinton and Kennard, and, so far as evidence from Wimbledon Common itself goes, I am aware of nothing to contradict it. It may, however, be worth adding to Mr. Johnson's account of the constituents of the gravel that rather large flints, some white-skinned, some cavernous, appear to be less rare than is usual on the Common itself in a high-lying gravel-pit on the Peek Estate close to Peek Crescent, now closed to the public. The most interesting stone that I have yet found on Wimbledon Common came from a pit near that named E by Mr. Johnson. It is a piece of white quartzite, measuring about 3 × 2 × 1 inches. It appears originally to have had a somewhat rectangular outline, but one surface is gently rounded and water-worn, while the other surface has been ground smooth and nearly flat except for broad, shallow, almost imperceptible furrows running across it, and is remarkably suggestive of glacial action. The exterior of the pebble has the usual reddish-brown stain of the gravel, and where a piece has been broken off, probably by frost, along pre-existing cracks, the interior is seen to be much paler. The interesting feature of the rock is that it is full of the external moulds and imprints of small cylindrical crinoid columnals, with cylindrical lumen and well-marked radiating ridges on the joint-faces. Within two days of my finding this, chance placed in my hands a piece of closely similar rock labelled "Halkin Burr". And I imagine that both specimens represent a Carboniferous sandstone such as is found in Flintshire. Among the constituents of the Wimbledon gravel, Mr. Johnson mentions "many discoidal cakes of pale-grey sandstone". These seem to belong to a different rock from the "red ferruginous grit", which he also mentions, but he does not discuss their origin. Are they not fragments of Sarsen stone?

In almost every exposure on Wimbledon Common and in the neighbourhood, the gravels are underlaid by sands resting on the

London Clay, and these sands have frequently been regarded as remnants of the Bagshot Beds. Certainly there often does appear to be a passage of these sands into the clay. On the other hand, it does not appear possible in any section to draw a clear line between these sands and the overlying gravel, so that one feels with Mr. Johnson it is safer to go no farther than to say "rearranged Bagshots".

Many an interesting question raised by the charming Beverley or beaver-brook is discussed, and this leads us on to the ancient Bensbury, absurdly called Cæsar's Camp, strongly entrenched on the dun from which the followers of Wimbald overlooked the Coombe.

It does not fall within our province to follow Mr. Johnson through the early mediaeval and modern history of the locality, though the geologist will not rightly comprehend some physical features if he forgets how many a superficial change has been due to Rifle Associations, Golf Clubs, and Conservators.

In other departments of natural history Wimbledon Common is so rich that a few omissions are not to be wondered at. It might, however, have been mentioned that the hawfinch is a regular resident and that the hedgehog is not uncommon. Mr. Johnson does well to enumerate the exotic trees of the neighbouring gardens, but he should not have forgotten the old cork-tree in Marryat Road. We read of Captain Marryat and his father, but not of Mrs. Marryat, F.R.H.S., to whom so much of our imported beauty is due. And how would Swinburne, who so loved this beauty, like to have been called "Sir Algernon"?

Truly Wimbledon Common should be in the mind of the public and especially of naturalists. Above all, just now, when its health and beauty are being threatened by the sale of lands in Kingston Vale, lands on which farming operations at present serve to intensify the rural charm of the scene, but which we dread to see covered with rows of mean streets, disfiguring the wonderful view and blackening the Common with their smoke. Our public-spirited fathers who lived round this Common had a hard fight to keep it, and its beauties have since been preserved for the public by a heavy annual expenditure on the part of the neighbouring residents. They it is who have dipped further into their own pockets to save the land to which we have just referred. Never before have they appealed to the public, but now time is running short and there is £19,000 yet to be raised before the end of July. They have done what they can, and now they are asking Londoners and others who share the Common with them to come to their help. Further information may be obtained from Mr. Richardson Evans, Secretary to the Extension Committee, The Keir, Wimbledon, and geologists should not be the last to send their subscriptions of whatever size to the Treasurer, Sir Robert Hensley, Glenton House, Putney.

F. A. Bather.

III.—Radio-activity and Geology.

The bearings of radio-activity on geology are discussed by Professor T. C. Chamberlin (*Journ. Geol.*, xix, November–December, 1911). He refers first to the old view that "the primitive gaseous or quasi-gaseous earth-mass was held to have passed later into a molten globe, and the subsequent incrusting of this to have entrapped in the interior the heat supply of subsequent ages". To the condensation of the nebula, whether gaseous or a quasi-gaseous meteoric swarm, was attributed the intense heat. An alternative view, developed by the author before the discovery of radio-activity, was the planetesimal hypothesis, which was "built on the belief that earth grew up gradually by the slow accession of discrete orbital matter", and that "the internal heat arose mainly from the self-compression of the earth-mass as it grew". The chief purpose of the present paper is to set forth the "harmony between the new light shed by radio-activity and the tenets of the planetesimal view". The original source of radio-active substances, so far as known, is in the igneous rocks; except in meteorites which appear to contain but meagre amounts of the substances, accessions of radio-active material from without the earth has not been demonstrated. It is pointed out that "from the igneous rocks the radio-active substances are dissolved and disseminated through the waters and carried wherever they go, while from both the rocks and the waters the emanations are given forth into the atmosphere". Therefore it is that radio-active matter is found "in practically all the rocks of the surface of the earth, in practically all the waters, and in practically all the atmosphere".

The author deals with the inference that liquefaction and eruption of the igneous rocks are dependent on the heat derived from radio-activity. Weathered igneous rocks are found to carry less radio-active matter than fresh rocks; nevertheless, soils "still retain notable radio-activity, but a part of this is probably a redeposit from the atmosphere".

The distribution of volcanoes past and present is referred to. The primitive shields, scarred with intrusions, are almost immune now; but they have suffered denudation, and "according to the hypothesis of concentration at the surface, this lost matter carried a relatively high proportion of radio-active substance".

The author supports the view, held by some geologists, that while "the rise of the denuded embossments of the crust was attended by elastic expansion of the whole sector of the earth beneath . . . that the protruding portions of the continents tend to lateral creep, and that this carries with it tensional effects as well as some further elastic expansion. At the same time the penetration of surface-water is promoted, and this aids effectively in carrying off the heat of the outer crust".

It is interesting, therefore, to remember that "the movement of igneous matter and of waters and gases heated by it has been made to play an essential part in the working concepts that have been based on the planetesimal hypothesis".

IV.—The Lower Palæozoic Corals of Chillagoe and Clermont. Part I. By R. Etheridge, jun. Queensland Geological Survey, Publication 231. pp. 8; plates A–D. Brisbane, 1911.

Of the five new corals that are described by Mr. Etheridge from the Lower Palæozoic of Chillagoe and Clermont, three are referred to the genus *Cyathophyllum* and two to *Spongophyllum*. *C. Dunstani*, n.sp., from Clermont, is related to two Devonian species of Europe and America—*C. quadrigeminum*, Goldfuss, and *C. hexagonum*, Goldfuss.

C. (?) *clermontensis*, n.sp., also from Clermont, is related to the Devonian species *C.* (?) *helianthoides*, Goldfuss, and *C.* (?) *damnoniense*, Goldfuss.

C. chillagoensis, n.sp., from Chillagoe, shows points of resemblance to and difference from *C. hypocrateriforme*, Goldfuss.

Spongophyllum cyathophylloides, n.sp., from Clermont, is compared with *S. bipartitum*, Etheridge, jun., from the Upper Silurian rocks of Yass, New South Wales; and *Spongophyllum* sp., a new form from Chillagoe, is distinguished from *S. cyathophylloides* by a limited number of septa and copious endothecal tissue.

The presence of the genus *Halysites* shows the Chillagoe Limestones to be of Silurian age, but that of the Clermont Limestone has yet to be determined.

V.—The Geology of Knapdale, Jura, and North Kintyre. By B. N. Peach, the late J. S. G. Wilson, J. B. Hill, E. B. Bailey, and G. W. Grabham: with notes by C. T. Clough, S. B. Wilkinson, W. B. Wright, and H. B. Maufe; and petrological descriptions by J. S. Flett. 8vo; pp. viii, 149, with 8 text-illustrations and 7 plates. 1911. Price 4*s.* 6*d.*

This memoir is an explanation of the Scottish Geological Survey Sheet 28, with parts of 27 and 29. Sheet 28, now issued (at the price of 2*s.* 6*d.*), is admirably colour-printed, and although it does not contain the whole of Jura, that island is fully described in the memoir without regard to the limits of the map.

Apart from the Glacial Drifts, the Raised Beaches, Alluvium and Peat, the area consists of Metamorphic Rocks (Dalradian), intersected by igneous dykes and some sills, the ages of which are doubtfully given as Old Red Sandstone, Permo-Carboniferous, and Tertiary.

Jura with its 'Paps', which rise to an elevation of more than 2,400 feet, is composed mainly of white quartzite. It is not a very hospitable-looking area, judging by the coast-views with raised beaches, but appears more attractive in the view of Dolerite dykes (plate vi).

The mainland is more varied in its geology, and consists of limestone, quartzite, clay-slate, and altered igneous rocks or 'epidiorites', which are folded together so that the outcrops of each run in long narrow strips directed mainly to the north-east. The numerous inlets by which the sea penetrates far inland (Loch Sween, Loch Tarbert, etc.) have the same trend as the rock outcrops, and are old land valleys which have been drowned by submergence. Around the coast is a remarkable series of raised beaches showing changes of the level of land and water, and indicating that the sea must at one time have stood at least 100 feet higher than at present. Photographs are reproduced in the volume to show the white gravels that cover these raised beaches on the west of Jura. There is also a fine view of pillow lavas associated with the black slate and limestones of the Loch Awe Group at An Aird. The concluding chapter contains an account of the mineral ores, glass sand, silica bricks, building-stones, slates, and other economic products of the district.

VI.—Brief Notices.

1. Coals of the State of Washington. By F. Eggelston Smith. Bull. cccclxxiv of U.S. Geol. Surv., 1911. pp. 1–206, with 8 plates.

THIS memoir contains a full account of each coal-working in the State of Washington, with geological sections and chemical analyses of the seams. There is also included an interesting detailed report of the methods of sampling, the chemical and physical properties of the coals, their impurities, and their uses.

2. The Recent and Fossil Mollusks of the genus *Alvania* from the West Coast of America. By Paul Bartsch. No. 1863. From the Proceedings of the United States National Museum, vol. xli, pp. 333–62, with plates 29–32. Washington, 1911.

A VERY complete account of Gastropod shells of the genus *Alvania* is given in this paper. Eighteen new species are described, and two of these are found as fossils, and as fossils only, viz. *A. pedroana* and *A. fossilis*, both from the Sand Rock at San Pedro, California. A history of research and a key to the genus precede the description of species. Most of the types of the new species were dredged by the United States Bureau of Fisheries steamer *Albatross.*

3. New Labyrinthodont from Kansas.—Labyrinthodonts are rare in the Coal-measures of North America, so the description of *Erpetosuchus kansensis*, Moodie, is especially welcome. The specimen consists of a fragment of a skull, two ribs, and the larger part of the left ramus of a mandible. These are preserved in the U.S. National Museum, and Mr. R. L. Moodie describes them in the Proceedings, vol. xxxix, pp. 489–95, 1911.

4. Water Divining and Radio-activity.—Mr. Beeby Thompson has given an account of some experiments which showed conclusively that three reputed 'water diviners', without any real knowledge of what they were about, were affected by the presence of radium emanation (Journ. Northamptonshire Nat. Hist. Soc., xvi, September, 1911). Mr. Thompson is not convinced that the diviners can be relied upon to find water, as in thirty-six records of their attempts in Northamptonshire, twenty were complete failures, and eight were virtual failures by reason of the fact that water was present everywhere below ground and one particular spot was no better than another. It is suggested that experiments be made on waters and rocks that are known to possess radio-active properties.

5. Dingle Beds.—In a report on the 'Dingle Bed' rocks in the Dingle Peninsula, co. Kerry (Proc. Roy. Irish Acad., xxix, section B, No. 7, 1912) Mr. Alexander McHenry comes to the conclusion that the true position of the strata is below the Wenlock rocks, and that they are probably of Llandovery age.

6. Gypsum Deposits of Canada.—A report on the Gypsum deposits of the Maritime Provinces, Nova Scotia, New Brunswick, and the Magdalen Islands, has been prepared by Mr. W. F. Jennison (Department of Mines, Canada, 1911). The report shows by descriptions, maps, and photographs the vast extent of the deposits, the uses of gypsum, and the processes and cost of manufacturing it into a marketable product. The Canadian gypsum deposits are all regarded as forming part of the Lower Carboniferous. The origin of gypsum is discussed, and the distribution of the mineral in various parts of the world is given.

7. Climatic Changes in Japan since the Pliocene Epoch.—This subject is discussed by Professor Matajiro Yokoyama (Journ. Coll. Sci. Tokyo, xxxii, art. 5, 1911). He concludes that the temperature in Central Japan has gradually increased since the earlier Pliocene, attaining its maximum in the Diluvial (Pleistocene), and then again decreasing to the present time. No evidence of glacial action has been met with in Japan.

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *January* 24, 1912.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communication was read:—

"The Upper Keuper (or Arden) Sandstone Group and Associated Rocks of Warwickshire." By Charles Alfred Matley, D.Sc., F.G.S.

Under the name of the Arden Sandstone Group the author describes the stratigraphy of a sandstone zone in the Keuper Marls of Warwickshire, which is exceptionally well exposed in the area formerly occupied by the Forest of Arden.

This zone varies in lithological composition and thickness. It is never wholly a sandstone, but always contains beds of light-grey and pale-green shale, marl, and mudstone, which in places make up almost the whole of the zone. The sandstone, where present, usually forms thin, flaggy, white or light-grey beds, and exhibits ripple-marks, current-bedding, and surfaces with footprints and sun-cracks. The zone contains *Estheria minuta*; plants; teeth, spines, and scales of fishes; tracks and remains of labyrinthodonts and reptiles; and occasional casts of molluscan shells. The band is typically 20 to 25 feet thick, increasing sometimes to 40 feet or more; but it thins, especially eastwards and south-eastwards, to 4 or 5 feet.

The zone was first described by Murchison & Strickland in 1837, but has not hitherto been completely mapped. The author traces it from the type-locality at Shrewley over an area of 108 square miles, and finds that it forms a continuous deposit at an horizon between 120 and 160 feet below the base of the Rhætic. He accepts the view of Murchison & Strickland, that it is the same formation as the Upper Keuper Sandstone of Worcestershire and Gloucestershire, and he also correlates with it the similar deposit at Leicester described by Plant. The formation thus appears to have been laid down over an area at least 70 miles in length, and was probably formed, as an episode in the history of the Keuper Marls, by an irruption of the sea into the Keuper Marl area. It represents a phase corresponding to that of the Rhætic Bone-Bed and the Tea-green Marls, but of somewhat earlier date.

The associated Keuper Marls have been examined, merely in order to establish their stratigraphical relations with the Arden Sandstone. So far as his observations go, the author is inclined to the view of the older observers that the Marls are aqueous deposits, though possibly containing much wind-borne material, deposited in a shallow lake undergoing strong evaporation and subjected to occasional irruptions of the sea. They represent the closing phase of Triassic 'continental' conditions in the English Midlands, when the slow subsidence which was soon to bring in marine Rhætic and Liassic deposits was in progress, and produced that overlapping of the Keuper rocks on to the higher grounds of the Triassic land-surface which is observable in the neighbouring districts of the Lickey Hills, Nuneaton, and Charnwood Forest.

The tectonics of the area are explained by sections and by a contour map of the upper surface of the Arden Sandstone, which show that, while the beds as a whole are tilted south-eastwards, there are numerous shallow cross-folds with Charnian (north-west to south-east) axes and others with Pennine (north to south) axes. The majority of the faults have a Charnian trend.

The paper also records three well-borings through the Marls into the Lower Keuper Sandstone.

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2. *February* 7, 1912.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communication was read:—

"On an Inlier of Longmyndian and Cambrian at Pedwardine (Herefordshire)." By Arthur Hubert Cox, M.Sc., Ph.D., F.G.S.

The inlier in question comprises a strip of country about a mile in length and half a mile in breadth, situated near the border of Herefordshire and Radnorshire, about 15 miles south of Church Stretton. It lies on the well-known north-east and south-west line of dislocation which extends through that town.

Wenlock and Ludlow Beds occupy most of the area around Pedwardine, but the occurrence of Cambrian Shale yielding *Dictyonema* has long been known. The *Dictyonema* Shales dip steeply westwards towards a series of red and green conglomerates and grits, with which an occasional thin shale-band is interbedded.

The latter beds, previously mapped as Llandovery, are here referred to the Longmyndian. They also dip steeply westwards, and have suffered considerable disturbance, accompanied by overthrusting from the west. They are quite unfossiliferous, and neither on lithological nor on structural grounds can they be regarded as Llandovery strata resting unconformably upon the Cambrian. Their nearest equivalents are found among the Longmyndian grits at Hopesay, and in the Bayston Group of the main Longmynd area. These Longmyndian grits at Pedwardine have apparently been carried south-eastwards over the Cambrian along an almost horizontal thrust-plane.

There is also present a small remnant of Bala grits which dip gently eastwards, and rest with strong unconformity upon the Cambrian shales. The undisturbed character of these Bala Beds suggests that the neighbouring thrust may be of pre-Bala date.

Later faulting along a north and south line has brought the members of these older formations against Wenlock and Ludlow Beds. From the greatly disturbed character of all the Silurian strata to the west of the inlier, as contrasted with the undisturbed condition of the beds on its eastern side, it would appear that this inlier is part of a barrier which has preserved the district lying to the east from the effect of the post-Silurian movements.

ANNUAL GENERAL MEETING.

3. *February* 16, 1912.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The Reports of the Council and of the Library Committee were read. It was stated that 47 new Fellows had been elected during the year, and that the losses by death, resignation, and removal amounted to 52 (1 more than in 1910), the actual decrease in the number of Fellows being, therefore, 5 (as compared with an increase of 5 in 1910). The total number of Fellows on December 31, 1911, was 1,294.

The Balance-sheet for that year showed receipts to the amount of £3,029 19*s*. 11*d*. (excluding the balance of £452 19*s*. 2*d*. brought forward from 1910) and an expenditure of £3,007 7*s*. 3*d*.

Reference was made to the transference of the collections in the Society's Museum to the authorities of the Natural History Museum and of the Museum of Practical Geology, and to the consequent extension of the Library.

The Reports having been received, the President presented the Wollaston Medal to Dr. Lazarus Fletcher, F.R.S., addressing him as follows:—

Dr. FLETCHER,—In the long list of distinguished men who have received from the Geological Society the Wollaston Medal, whether struck in palladium or in gold, there are not only many geologists of great eminence for their studies in other branches of the science, but a preponderance of those whom the donor doubtless had more particularly in mind in founding his Medal 'to promote researches concerning the mineral structure of the earth'. The list does not contain the names of many pure mineralogists, but in asking you to accept the Medal this year the Council has desired to place you in company with Bischof, Naumann, Dana, von Hauer, Des Cloiseaux, Story Maskelyne, and von Groth. Succeeding in the Keepership of the Mineralogical Department of the British Museum to the real founder of that Department, and the one who made it an expression of the best side of mineralogical science, you impressed your own personality upon it, and left it more valuable, more useful, more representative, more simple. The last was no light task, and it required, in a mathematician of such high culture and ability, an extraordinary and very unusual type of intellect to write an introduction to the study of minerals, and to arrange a collection to illustrate it, without the use of a single mathematical expression; and yet to produce a book which is at once intelligible to the museum visitor, a scientific guide to the student, and a joy to the professed mineralogist. If this were all it would be a great achievement, but you have done as much for the study of rocks and even of meteorites. And all the time you have been engaged in research of a most painstaking and minutely accurate character on the constitution of meteorites and of certain obscure and rare minerals, leaving, with characteristic unselfishness, the more attractive problems to your colleagues. If we add to this your theoretic work on the effect of heat on crystals, your elegant treatment of crystallographic optics, culminating in the conception of the optical indicatrix, your fastidious and dainty choice of expression in order to eliminate the slightest trace of ambiguity from your descriptive work, and, finally, your steadfast devotion to the well-being of the Mineralogical Society, with which you have been so closely identified, we have a record of devotion to your science and duty which has, to the delight of your friends, been worthily crowned by your appointment to the Directorship of our great National Museum of Natural History.

I ask you to accept the Wollaston Medal, not for the sake of yourself and your work alone, but as a token of acknowledgment by the Science of Geology of part of her debt to the science which you so worthily represent in our country.

Dr. Fletcher replied in the following words:—

Mr. President,—I thank the Council very heartily for the distinction that has been conferred upon me by the award of this medal, given more especially, I am told, for my researches in connexion with the crystalline forms and crystal optics.

Each recipient of the Wollaston Medal must have heard with a thrill of pleasure the news that such a compliment had been paid to him by his fellow-workers; but doubtless the pleasure has been especially great to the crystallographers, for they cannot but have felt that crystallographic researches deemed worthy of such recognition must have brought some additional honour, however slight, to the memory of the many-sided Wollaston, who, by his invention of the reflective goniometer, had first made possible the measurement of crystalline forms with astronomical precision.

As regards crystal optics, the subject is too abstruse to appeal to the popular imagination. But, for the mathematician at least, there is wonderful beauty in the thought that, for every biaxal crystal, notwithstanding all our uncertainties relative to the luminiferous ether, to each point on an ellipsoid there corresponds a single ray of light, with three physical characters—namely, the direction and velocity of transmission and the plane of polarization—all definitely and simply related to the geometrical characters of the ellipsoid at that point. I may mention that it was some time after the perception of this relationship before I could convince myself of its truth; for it seemed that, after the harvest that had been gathered from the wave-surface by Fresnel, Sir William Hamilton, MacCullagh, Sylvester, and others, nothing was left for the gleaner, and that the relationship, if true, would have been discovered long ago.

It may be not without interest if I add that the direction of my work in life has been much influenced by two Wollaston Medallists, Professor P. von Groth and the late Professor Maskelyne. In the year 1876, when I was Demonstrator in Physics for Professor Clifton at Oxford, I saw a new book lying on his study table: it was Groth's *Physikalische Kristallographie*, then just published.

I was so much interested in scanning its pages that I ordered a copy, and read it slowly and carefully at my leisure. Professor Clifton mentioned my interest in crystals to his Oxford colleague, that enthusiastic crystallographer, Professor Maskelyne, and I was invited to call at the British Museum; the visit had for result a brief official connexion with him in the Mineral Department, and, what was still more important, a long-continued friendship that ended only with his life thirty-four years later. To both of them I am thus under a heavy debt of gratitude.

The President then presented the Murchison Medal to Professor Louis Dollo, F.M.G.S., addressing him as follows:—

Professor DOLLO,—The Council have awarded you the Murchison Medal in recognition of the importance of your numerous contributions to our knowledge of Vertebrate Palæontology. Twenty-three years ago they encouraged your early work by the award of the Lyell Fund, and since that time the Society has continued to follow your researches with interest, enrolling you first as a Foreign Correspondent and then as a Foreign Member. The promise of your earliest publications on the Wealden Reptiles of Bernissart has been fulfilled in your later papers on the Cretaceous Mosasaurians and various other vertebrate fossils; and your philosophical insight has illumined many difficult problems which other authors found obscure. I need only refer to your interesting essays on the evolution of the Dipnoan Fishes, on the auditory apparatus of Mosasaurians and Ichthyosaurians, and on the feet of Marsupials, which are classics in modern palæontological literature. Your demonstration of the principle of 'irreversibility' in organic evolution has led to important conclusions which are now generally appreciated; and your treatise on ethological palæontology has opened the eyes of observers to the evidences of correlation between structure and function which may be observed in several classes of fossil animals. Your papers never fail to embody suggestions which are stimulating and conducive to new points of view.

Professor Dollo, in reply, said—

Monsieur le Président,—Permettez-moi d'exprimer mes sentiments de profonde reconnaissance à la Société géologique de Londres pour le grand honneur qu'elle veut bien me faire en me décernant la Médaille de Murchison.

Il y a près d'un quart de siècle déjà, votre Société eut la bonté d'encourager mes premiers travaux, en m'attribuant le Fonds Lyell: c'était le temps des Iguanodons et des Mosasaures.

Depuis, sans jamais cesser de m'occuper des Reptiles fossiles, j'ai été amené à aborder de multiples problèmes de Paléontologie éthologique, et, même, tout récemment, il me fut donné, à cette occasion, de faire une incursion dans le Monde silurien. La grande ombre de Murchison a accueilli ma hardiesse avec indulgence, puisque je puis, aujourd'hui, vous assurer de ma gratitude, en recevant la Médaille fondée par cet illustre Géologue.

Mais je n'en ai pas fini avec les Reptiles fossiles de la Belgique, dont, prochainement, je suis heureux de pouvoir vous l'annoncer, le Musée de Bruxelles exposera une importante série nouvelle, provenant des Terrains éocène, oligocène et miocène, notamment un squellete gigantesque, presque complet, de l'*Eosphargis gigas*, découvert d'abord en Angleterre.

Et, maintenant, commencent à arriver les Reptiles fossiles du Congo, encore très fragmentaires, mais pourtant caractéristiques, dont j'ai pu signaler les premiers restes à l'Académie royale de Belgique, au début de cette année.

Après trente ans de carrière, une tâche considérable se dresse donc encore devant moi: en cette occurrence, la Médaille de Murchison sera un stimulant précieux, qui me soutiendra dans mes efforts, et c'est pourquoi je vous en remercie.

In presenting the Lyell Medal to Philip Lake, M.A., the President addressed him as follows:—

Mr. LAKE,—As an old friend of many years' standing, I regard it as a great privilege to hand you the Lyell Medal which the Council has awarded to you, as to one who 'has deserved well of the Science'. But your work has been so many-sided, that it is not easy to choose that on which to lay the chief emphasis. You have dealt with the stratigraphy and tectonics of the older Palæozoic rocks in those more difficult regions which have been left by other observers till last, as in the Dee Valley and about Cader Idris. You have treated of the petrology and the structural relations of both interbedded and intrusive igneous rocks, and in doing so have carried down our knowledge of igneous activity well into the Cambrian Period. You have utilized your knowledge of the structure and relations of the rocks, and the superficial deposits resting upon them, to form a theory as to the history of the Dee and of Bala Lake, and have applied this theory to the general drainage system of North Wales. And last, but far from least, you have done much to elucidate the structure and classification of certain forms of Trilobites, more especially *Acidaspis*, and are now engaged upon an elaborate monograph, part of which is already published, on the Cambrian Trilobites, a work the need for which has long been felt by workers among the older rocks in this country. Your services to Geology do not end here, for by your teaching and organization you have contributed much to the study of geology and geography in Cambridge and its vicinity; while by your translation and adaptation of Kayser's *Comparative Geology*, and the publication, in conjunction with Mr. Rastall, of your Textbook, you have placed the students of stratigraphical geology deeply in your debt.

Mr. Lake, in reply, said—

Mr. President,—I am deeply sensible of the honour that the Council has conferred upon me by the award of the Lyell Medal.

It is an especial pleasure to find in the list of former recipients the names of two of those to whom I am most indebted for my geological training—Professor Hughes and Dr. Marr.

But I do not forget that it is to Professor Lebour, one of the Murchison Medallists, that I owe my first introduction to geology. Without his guidance and help I should never have become a geologist, nor should I ever have come under the influence of Cambridge.

Circumstances have seldom permitted me to devote my undivided attention to the study of our science, and my geological work has suffered accordingly. It is encouraging to find that it has not altogether failed, and I still hope in the future more fully to justify the award for which I now thank the Council.

In presenting the Balance of the Proceeds of the Wollaston Donation Fund to Charles Irving Gardiner, M.A., the President addressed him in the following words:—

Mr. Gardiner,—The vacation times of a man so strenuously occupied as yourself are very precious to him, and it is a compliment to the fascination exercised by scientific research, and especially by the pursuit of geological investigation, that you willingly give up so much of your holidays to field-work in your chosen science. Mainly in association with Professor Reynolds, you have patiently and unweariedly carried out your steadfast programme, which I am glad to think was suggested to you by myself, of increasing our knowledge of the older Palæozoic rocks of Ireland. Beginning at Kildare, you passed thence by way of Lambay to Portraine, at each stage throwing new light on the succession, and at the last-named locality unravelling the different types of conglomerates, which in that neighbourhood have been produced by earth-movement. Shifting your operations to the south, you threw new light on the succession of Silurian rocks in that region and on the unusual association of contemporaneous igneous rocks with them. Then you proceeded to Mayo and Galway, dealing with the areas of Tourmakeady, Lough Nafooey, and Glensaul in turn; and, judging by your latest paper, you seem to have been as successful in this exceedingly difficult ground as in the simpler areas previously dealt with. The Council, in awarding you the Balance of the Proceeds of the Wollaston Fund, does so, not only in recognition of good work done, but in confidence that you will carry on similarly good work in the future.

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Dr. Arthur Morley Davies, addressing him as follows:—

Dr. Morley Davies,—It is recognized by your friends and colleagues that the original work which you have completed has been accomplished under singular difficulties and in the stress of a very busy life. You have been specially attracted by the series of anomalous deposits, which in various parts of Buckinghamshire and the vicinity come between the Oxford Clay and the Chalk, and several members of the sequence have been elucidated by your careful and detailed stratigraphical and palæontological research. You have collected many of these results, and combined them with other information, in your clear and concise summary of the Geology of Buckinghamshire published in *Geology in the Field.* You have spent much thought and industry on the preparation of a tectonic map of the British Isles, a work long needed by geologists, and one which we hope will shortly see the light. You have sympathies also with the geographic side of science, as testified by your work on the *Geography of the British Isles*, your admirable little volume on the Geography of Buckinghamshire, and a number of papers dealing with such subjects as lie on the borderland between history and geography. You will perhaps also allow me to express here my very warm appreciation of the great value of your work as a colleague at the Imperial College of Science and Technology, and it is this which makes it an exceptional pleasant duty for me to hand you the Balance of the Murchison Fund during my last year of office.

In presenting a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Dr. Arthur Richard Dwerryhouse, the President addressed him as follows:—

Dr. Dwerryhouse,—When, as Secretary of the Society, it was my duty to read the manuscript of your paper on the Glaciation of the Valleys of the Tees and other northern rivers, I got the impression that it was a model of scientific exposition, an opinion confirmed when I saw it in print. But this represents only a part of the service that you have rendered to the Glacial Geology of the North and Midlands of England and of the North of Ireland. In each locality you have discovered something new and something throwing fresh light upon the conditions that prevailed during the Glacial Epoch. But you have also been able to pursue inquiries along other lines; for instance, the circulation of underground waters, the origin of caves, and the weathering of rocks, while in your Presidential addresses to the Liverpool Geological Society you have dealt with far larger geological problems. As a contributor to the *Glacialists' Magazine*, as Secretary for several years of Section C of the British Association, and as a member of the Committee on Erratic Blocks, you have discharged other duties to your science. In your papers on the Eskdale Granite and its metamorphism, you have approached a difficult petrographical problem, and made an important contribution to its solution. Finally, your recent work on geological maps will be of great help in educating students to deal in the laboratory with geological problems which they will have later to face in the field. I have the pleasure to hand you a moiety of the Balance of the Proceeds of the Lyell Geological Fund.

The President then presented the other moiety of the Balance of the Proceeds of the Lyell Geological Fund to Robert Heron Rastall, M.A., addressing him as follows:—

Mr. Rastall,—It is fitting that both authors of so novel and important a work as *Lake and Rastall's Textbook* should receive awards from the Geological Society on the same occasion. In making this award, however, the Council had in mind not only that work, but the labour which you have for many years devoted to your science in original research. You have been attracted most strongly by petrographical problems, as is indicated by your contributions to Dr. Hatch's work on that subject, by your papers on the igneous rocks of Buttermere and Ennerdale, on the inclusions in the Mount-Sorrel granite, on the Skiddaw granite, on the rocks surrounding the Kimberley diamond pipes, and on the dedolomitization of marble at Port Shepstone. One might perhaps even venture to think that your chief interest in the Cambridgeshire boulders was aroused by the numerous rock-types which are thus to be found scattered over a country not otherwise rich in problems of the more solid geology, were it not for your contribution on the Cambridge district to *Geology in the Field.* You have not neglected other sides of the science, and your paper on the Dogger of Blea Wyke and that on the Ingletonian Series are important contributions to our detailed knowledge of the position and character of these strata. Your latest paper has dealt with your observations in South Africa, and involves, not only an important elucidation of the tectonics of the area, but, if its conclusions are accepted by South African geologists, a new reading of the relations of the strata there. It is my pleasant duty to hand to you the Balance of the Proceeds of the Lyell Fund.

The President thereafter proceeded to read his Anniversary Address, giving Obituary Notices of several Foreign Members, Foreign Correspondents, and Fellows deceased since the last Annual Meeting, including Dr. A. Michel-Lévy (elected a Foreign Member in 1893); M. Édouard Dupont (el. 1897); Dr. C. A. White (el. 1899); Professor G. Stefanescu (elected a Foreign Correspondent in 1899); Dr. A. E. Törnebohm (el. 1910); Sir J. D. Hooker (elected a Fellow in 1846); Professor T. Rupert Jones (el. 1852); Professor N. Story Maskelyne (el. 1854); G. Maw (el. 1864); G. P. Wall (el. 1862); F. Braby (el. 1864); G. Attwood (el. 1872); S. F. Emmons (el. 1874); W. Shone (el. 1874); R. D. Roberts (el. 1875); Rev. E. M. Cole (el. 1889); G. E. Coke (el. 1901); and A. Longbottom (el. 1909).

He then made reference to the chief event of the year in the Society's affairs—the transference of the collections in the Museum to the authorities of the British Museum (Natural History) and of the Museum of Practical Geology; and dwelt at some length on the consequent re-arrangement and extension of the Library.

The main subject of the Address was a consideration of the methods to be adopted for determining the actual extent of this country's natural resources in the matter of coal, and the President remarked that the inquiries of the Coal Commissions have shown that, of the coal left unworked in Britain, 100,000 millions of tons remain in the proved and 40,000 millions in the unproved coal-fields. It is pointed out that it is as safe to reckon confidently on the latter quantity as on the former.

Careful estimates by competent authorities show that this quantity of coal is likely to become exhausted between 2130 and 2200 A.D. according to the precise basis upon which the calculation is made.

It becomes, therefore, a serious matter to ascertain whether or no we possess other supplies of workable coal not included in the estimate of the Commissioners, and it is pointed out that in Eastern and Southern England there exists an area of Palæozoic rocks unconformably covered by Neozoic rocks larger in extent than the uncovered Palæozoic outcrop of England and Wales.

This area has only been explored in regions which are in direct prolongation of the exposed coal-fields, and by a very small number of borings put down elsewhere. Some of these have demonstrated the existence of Coal-measures or other Carboniferous rocks, and none have yet proved a Neozoic cover so thick as to preclude the possibility of successfully working any coal which may be found beneath it.

It is argued that the time has now come for the organization of a systematic survey of this area by means of a considered series of borings so planned as to investigate the structure of the concealed Palæozoic floor, to ascertain the thickness of cover, to locate any coal-basins which may form part of the floor, and to elucidate their exact tectonic conditions in order to determine their suitability for profitable working.

It is admitted that such an exploration would involve many practical difficulties and would introduce a new practice into British institutions, but it is pointed out that similar methods have been employed in foreign countries and even in British Colonies.

It is urged that the close dependence of the future of the nation on its coal-supplies justifies a new departure, and that it would be a wise act of statecraft to take deliberate measures to devise a comprehensive and well-considered scheme of exploration, the results of which might be at hand for application before the growing scarcity of coal shall have begun to produce its inevitable economic consequences upon the manufactures and upon the very conditions of existence in this country.

The Ballot for the Council and Officers was taken, and the following were declared duly elected for the ensuing year:—

OFFICERS:—*President:* Aubrey Strahan, Sc.D., F.R.S. *Vice-Presidents:* Professor Edmund Johnston Garwood, M.A.; John Edward Marr, Sc.D., F.R.S.; Richard Dixon Oldham, F.R.S.; Professor W. W. Watts, Sc.D., LL.D., F.R.S. *Secretaries:* A. Smith Woodward, LL.D., F.R.S., F.L.S.; Herbert Henry Thomas, M.A., B.Sc. *Foreign Secretary:* Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S. *Treasurer:* Bedford McNeill, Assoc.R.S.M.

The other Members of COUNCIL are:—Henry A. Allen; Tempest Anderson, M.D., D.Sc.; Charles William Andrews, B.A., D.Sc., F.R.S.: Henry Howe Arnold-Bemrose, J.P., Sc.D.; Professor Thomas George Bonney, Sc.D., LL.D., F.R.S.; Professor William S. Boulton, B.Sc., Assoc.R.C.S.; James Vincent Elsden, D.Sc.; John William Evans, D.Sc., LL.B.; Robert Stansfield Herries, M.A.; Herbert Lapworth, D.Sc., M.Inst.C.E.; George Thurland Prior, M.A., D.Sc.; Clement Reid, F.R.S., F.L.S.; Arthur Vaughan, M.A., D.Sc.; and the Rev. Henry Hoyte Winwood, M.A.

CORRESPONDENCE.

DISCOVERY OF HUMAN REMAINS. OBLITERATION OF TRACES OF INTERMENT.

SIR,—A skeleton has just been found buried in the top of the Barrington Beds under circumstances which are at the present time of special interest.

'Barrington Beds' is the name given to a deposit of freshwater origin occurring over an area of very limited extent near the village of Barrington, some seven miles south of Cambridge. The locality has recently been visited by the Geologists' Association, and described in their Proceedings (vol. xxii, pt. v, p. 268, 1911).

I took a party of students there yesterday to examine the sections and in order to facilitate our work I employed labourers to remove the top. At the bottom of the surface soil, exactly where the head of the man in the white straw hat comes in fig. 1 of the report above referred to, the workmen came upon the bones of a child about twelve years of age. There was nothing, as far as I could ascertain or see, in the appearance of the overlying soil to suggest an interment until the bones were reached. There was, however, a small irregular depression excavated in the top of the underlying chalky loam, and in this the body lay as if it had been buried in a contracted position. The bones were crushed and disturbed by the settling down of the overlying earth during the decay of the soft parts, and were much decomposed, but there was nothing obviously abnormal in them. In such cases we have to remember that the surface soil is always on the move, and that all traces of a grave or other pit quickly disappear in a homogeneous superficial deposit. It is only where there are stratified beds of sand or gravel and the continuity of the layers is interrupted that the infilled grave or pit can be clearly seen in section.

I once saw a remarkable case of the obliteration of the signs of interment at Faversham in North Kent. Here an interesting cemetery of Roman and Saxon age was entirely carried away in the course of digging for brickearth. In the face of earth seen in section at the time I refer to, the bones in the Saxon graves were exposed at a depth of about $1\frac{1}{2}$ to 2 feet, and some 4 feet lower the Roman skeletons were seen.

In ordinary dry states of the weather the earth above the skeletons showed no sign of having been moved, and there was nothing obvious in its condition to indicate in either the one case or the other that there had been any interment. The graves had been dug in homogeneous yellowish-brown brickearth, and there were no lines of stratification or stony beds cut across to betray the disturbance. But the loosening of the earth had permitted a more free percolation of surface-water in the graves, and had in this way produced a small change in the texture of the loam, which was indicated in damp weather by a slightly darker colour in the moved soil.

In view of these facts I attach no importance to the absence of any signs of disturbance in the soil above the skeleton at Barrington. I believe that the Ipswich skeleton occurred under exactly similar conditions. It showed, as I was informed, no signs of disturbance in the earth above the bones, which were in a small irregular depression in the underlying sand. This sand is that called by Searles Wood 'Middle Glacial'. The earth above the skeleton was simply 'soil', 'head', 'run of the hill', or 'trail', but there was, I feel sure from what I saw, no Boulder-clay overlying the skeleton.

T. McKenny Hughes.

February 28, 1912.

STRATIGRAPHICAL NAMES.

Sir,—I think Dr. Bather has done well to call attention to the growing necessity for some official control over geological nomenclature. The introduction of a new name for any stratigraphical unit ought to be regarded as a serious matter, which cannot receive too much consideration, and it should certainly have the sanction of a responsible committee. This is desirable not only to prevent the duplication of names and the proposal of unnecessary names, but also on behalf of a good and necessary name, which would thus stand a better chance of being generally adopted.

Being myself responsible for the proposal of several stratigraphical names I can fully understand both the positive and negative advantages of submitting them to a committee, and one practice which such a committee could practically prevent, by refusing to sanction it, is that of giving formal geographical names to divisions which have no greater importance than zones.

Moreover, there are cases where the same stage is known by different names in different countries, and if such tribunals existed in two or more European countries they might combine to decide which of the two names should be adopted.

I think the committee might be appointed by the Council of the Geological Society and its members hold office for a term of years, and that it might consist of seven members, with the proviso that one was always chosen from the staff of the Geological Survey.

A. J. Jukes-Browne.

Torquay.
March 9.

OBITUARY.

R. B. BROCKBANK.

Born 1824. Died January 31, 1912.

The late Richard Bowman Brockbank, who died at The Nook, Crosby, near Maryport, Cumberland, on January 31, in his 88th year, was a much-esteemed member of the Society of Friends, and was well known in the district around Carlisle as an able farmer and breeder of excellent horses and cattle. To the geologist he is notable as the discoverer of the fact that the shales and limestone bands around Great Orton and Aikton, west of Carlisle, are of Liassic and not (as then supposed) of Carboniferous age. He called the attention of E. W. Binney to the subject, and Binney has described what he saw of the Lias of Cumberland in Quart. Journ. Geol. Soc., vol. xv, p. 549. More detailed observation, on the part of the present writer, has added but one section to those shown to Binney (see Geol. Survey Mem., *Geology around Carlisle*). For the ground is persistently drift-covered, and any sections in the underlying rocks are very few and small.

In addition to being shown the positions of sections in the Lias, I have to thank Mr. R. B. Brockbank for much information kindly obtained for me with regard to old borings and observations that would otherwise have remained unnoticed, and which have a special value in a district of this kind.

T. V. Holmes.

CHARLES ROEDER.

BORN JULY 22, 1848. DIED SEPTEMBER 9, 1911.

CHARLES ROEDER was a native of Gera, Thuringia, and came to this country when 21 years of age as a clerk in a Manchester shipping house. He later started in business for himself as an agent for several important Continental and English manufacturers.

He devoted a large measure of his spare time in research work of various kinds, geology, botany, philology, and history being his chief subjects. Prehistoric archæology, also, came in for a good share of his time in later life.

His geological investigations were by no means small, and one has only to peruse the Transactions of the Manchester Geological Society and various other local journals in order to gain some idea of his work in this science.

The sections of Upper Coal-measure and Permian strata exposed in cutting the railway from Fallowfield to Levenshulme, on the south side of Manchester, afforded him excellent opportunities to pursue one of his pet subjects. To him science is especially indebted for a knowledge of these beds. With unflagging energy he examined and measured this section inch by inch, collecting, often with considerable difficulty, the various fossils contained therein, afterwards forwarding the results of his labours to Messrs. Jones and Kirkby, Professor Geinitz, and others, for expert examination and identification. In his honour a new species of Ostracoda was named by Messrs. Jones and Kirkby, viz. *Carbonia roederiana.*

Mr. Roeder later presented a fine series of fossils from this and many other localities at home and abroad to the Manchester Museum.

J. W. J.

ROBERT CAIRNS.

BORN 1854. DIED DECEMBER 29, 1911.

BY the death of Mr. Robert Cairns, which took place from heart failure at his residence, Hurst, Ashton-under-Lyne, Lancashire loses a well-known local geologist. The deceased came to Ashton from Hawick, Roxburghshire, about 1875, and for many years acted as assistant to Mr. Abraham Park, J.P., at the Albion Schools. This position he relinquished later in order to take over the headmastership of the Hurst Undenominational (Old British) School, which he held for the past thirty-five years.

He was a man of wide culture and endowed with a strong personality that brought him numerous friends. As an enthusiastic geologist and conchologist he made a name for himself among a wide circle of local naturalists.

For many years he assiduously collected fossils from the numerous coal-pits lying between Ashton and Oldham, and formed an extensive and valuable collection of fish and other remains. During the sinking operations of the Ashton Moss pit, at Audenshaw, he took advantage of the excellent opportunity afforded of collecting and studying the various fossils met with, and by his unwearied labour got together a fine series of interesting specimens. He also collected extensively from the well-known 'marine band' in the Middle Coal-measures exposed on the banks of the River Tame at Dukinfield, *Aviculopecten cairnsii*, Bolton, from this horizon being named in his honour.

Further afield the Mountain Limestone areas around Castleton, Derbyshire, and Clitheroe, Lancashire, came in for a large share of his spare time, and by his keen perseverance he amassed a considerable collection of interesting forms from both these places.

When he began to seriously take up conchology as his hobby the exigencies of space led him to hand over *en bloc* his entire collection of geological specimens to the Manchester Museum, an acquisition which was gratefully accepted by the Museum authorities as a very welcome addition.

Though he could never be persuaded to write anything about his varied experiences, he was ever ready to place his wide and practical knowledge at the disposal of his friends.

J. W. J.

GEORGE ATTWOOD,

F.C.S., M.Inst.C.E., F.G.S., etc.

Born 1845. Died February 9, 1912.

Mr. George Attwood, J.P., who died on February 9 last at his residence, Steyning Manor, Stogursey, Somerset, was the son of the late Mr. Melville Attwood, F.G.S., etc., mining and civil engineer, and nephew of the late Professor Edward Forbes, F.R.S., Edinburgh, and David Forbes, F.R.S. Mr. Attwood was born at Carlisle in 1845, and educated at Edward VI's Grammar School, Lichfield. He was a member of the Institute of Civil Engineers, the Institute of Mining and Metallurgy, and the American Institute of Mining Engineers; Fellow of the Geological, Chemical Faraday, and Zoological Societies, and of the Society of Arts; a member of the London Chamber of Commerce; and Justice of the Peace for the Province of British Columbia. He commenced his professional career at the age of 16, under his father and Mr. W. W. Palmer, C.E., in California and Nevada, and two years later was appointed assayer, metallurgist, and chemist to the Ophir Company, Great Comstock Lode, Nevada, U.S.A. He constructed and designed large metallurgical, electrical, and water works, aerial tramways and railways in Nevada, California, Mexico, South America, Canada, South and North Africa, and practised as a consulting civil and mining engineer at 56 Moorgate Street, E.C., under the name of Messrs. Attwood & Hopper. Mr. Attwood also found time for considerable literary work, being author of numerous scientific publications and papers on geology, mining, mining plant, metallurgy, assaying, meteorology, microscopic research, etc. He was one of three or four surviving male descendants of an ancient Worcestershire family which came originally from Brittany, whose name 'De Bois' was anglicized into 'Attwood'. Members of the family were knights of the shire as early as 1327. He married first Maria Louise (who died in 1892), daughter of James Tansley, F.S.A., of London, and secondly Charlotte Caroline, daughter of William Burchell, late Under-Sheriff of London.

The late Mr. Attwood was frequently called upon to advise British mining companies when in some difficulty. This was notably the case in the early seventies with the Emma Silver Mining Company, Ltd., of Utah, U.S.A., floated by Baron Grant, and sold by him for £1,000,000 sterling. Mr. Attwood was asked to visit the Emma Mine and report upon it. He did so, and what he had to say was distinctly unfavourable. On many subsequent occasions the services of this distinguished engineer were in request, and his reputation was always of the very highest. The mining profession is greatly benefited by the association of such reliable and honourable men as the late Mr. George Attwood.—From the *Mining World*, February 24, 1912.

MISCELLANEOUS.

A Deep Boring in Gotland.—A boring recently completed in the grounds of the cement factory at Kopparsvik just south of Visby is of interest, first as the deepest boring yet effected in Sweden, exceeding that at Kiruna by 29 metres; secondly, as passing from the Silurian (Lower Wenlockian) through the Ordovician and possibly Cambrian to the gneiss floor. Started last year by the factory to discover the depth of its clay, the work was ultimately finished by the Geological Survey of Sweden, which will study and publish a report on the cores. The total depth of the borehole is 390 metres (*circa* 1,275 feet) below sea-level. Clay persisted to a depth of 140 metres, and was followed by 100 metres of pure limestone; then came 40 metres of shales, and, at a depth of 280 metres, sandstone mixed with shales. The gneiss was touched at 386 metres. At intervals below the depth of 200 metres a strong smell of petroleum was noticed. The boring was carried out by the Swedish Diamond Rock-boring Co., Stockholm. We may expect that, in the competent hands of our Swedish colleagues, the cores will give much-needed information as to the passage beds between Silurian and Ordovician in this part of the Baltic.

Croydon Bourne.—It is not surprising after the heavy rains of the past three months that the Croydon Bourne reappeared on February 7. The outbreak was predicted by Mr. Baldwin Latham, M.Inst.C.E., who has on fourteen previous occasions, 1877–1910, successfully foretold the time when this 'Woe Water' would break out.

Royal Society.—As announced by the President, Sir Archibald Geikie, in his Anniversary Address delivered on November 30, the Royal Society will celebrate its 250th birthday on July 15 of this year. Although the Society originated from meetings held by certain Natural Philosophers about the year 1645, it was not until July 15, 1662, that the Charter of Incorporation passed the Great Seal and the Society was fully established. Among the original Fellows whose labours and writings dealt to some extent with matters geological, were John Aubrey, Robert Hooke, Sir William Petty, and Sir Christopher Wren. The Society has invited the chief universities, academies, scientific societies, and other institutions in this country, in our Colonial Dominions and elsewhere abroad, to send delegates to the meeting. It has also been arranged to issue a new edition of *The Record of the Royal Society.*

LIST OF NATURAL HISTORY AND SCIENTIFIC BOOKS AND PAPERS ON SALE BY

DULAU & CO., LTD., 37 SOHO SQUARE, LONDON, W.

ADAMS (F. D.) & BARLOW (A. E.). Geology of the Haliburton and Bancroft Areas, Province of Ontario. Ottawa, 1910. 8vo. pp. viii, 419, with maps and numerous illustrations. 3*s.*

ARBER (E. A. N.). The Coast Scenery of North Devon: being an account of the geological features of the coastline from Porlock to Boscastle. London, 1911. 8vo. pp. 286. Illustrated. 10*s.* 6*d.*

BAROIS (J.). Les irrigations en Egypte. 2e édit. Paris, 1911. Roy. 8vo. With 17 plates. Cloth. £1 8*s.*

BOWMAN (I.). Forest Physiography: Physiography of the United States and Principles of Soils in Relation to Forestry. New York, 1911. 8vo. Cloth. 21*s.*

BRAUNS (R.). Die Kristallinen Schiefer des Laacher Seegebietes und ihre Umbildung zu Sanidinit. Stuttgart, 1911. 4to. pp. 61. With 18 plates. In portfolio. £1 4*s.*

BRINSMADE (R. B.). Mining without Timber. London, 1911. 8vo. Cloth. 12*s.* 6*d.*

BRUN (A.). Recherches sur l'exhalaison volcanique. Genève, 1911. 4to. pp. 277. With 34 plates and 17 illustrations in the text. £1 4*s.*

CHURCH (A. H.). Precious Stones considered in their scientific and artistic relations. 3rd ed. London, 1908. 8vo. 4 plates. 1*s.* 6*d.*

CLARK (W. B.) & MATHEWS (E. B.). Report on the Physical Features of Maryland. Baltimore, 1906. 8vo. pp. 284. With many plates. Cloth. 5*s.*

COLE (G. A. J.). The Changeful Earth: an introduction to the record of the rocks. London, 1911. 8vo. Cloth. 1*s.* 6*d.*

COLLINS (H. F.). The Metallurgy of Lead. 2nd ed. London, 1911. 8vo. pp. 558. Cloth. £1 1*s.*

COUES (E.). Fur-bearing Animals: Monograph of North American Mustelidæ. Washington, 1877. 8vo. With 20 plates. Cloth. 7*s.*

DARWIN (C.). Geological Observations on the Volcanic Islands and parts of South America visited during the voyage of H.M.S. *Beagle.* 3rd ed. London, 1891. 8vo. pp. 648, with maps and illustrations. Cloth. 6*s.*

DENDY (ARTHUR). Outlines of Evolutionary Biology. London, 1912. 8vo. pp. 468. Cloth. 12*s.* 6*d.*

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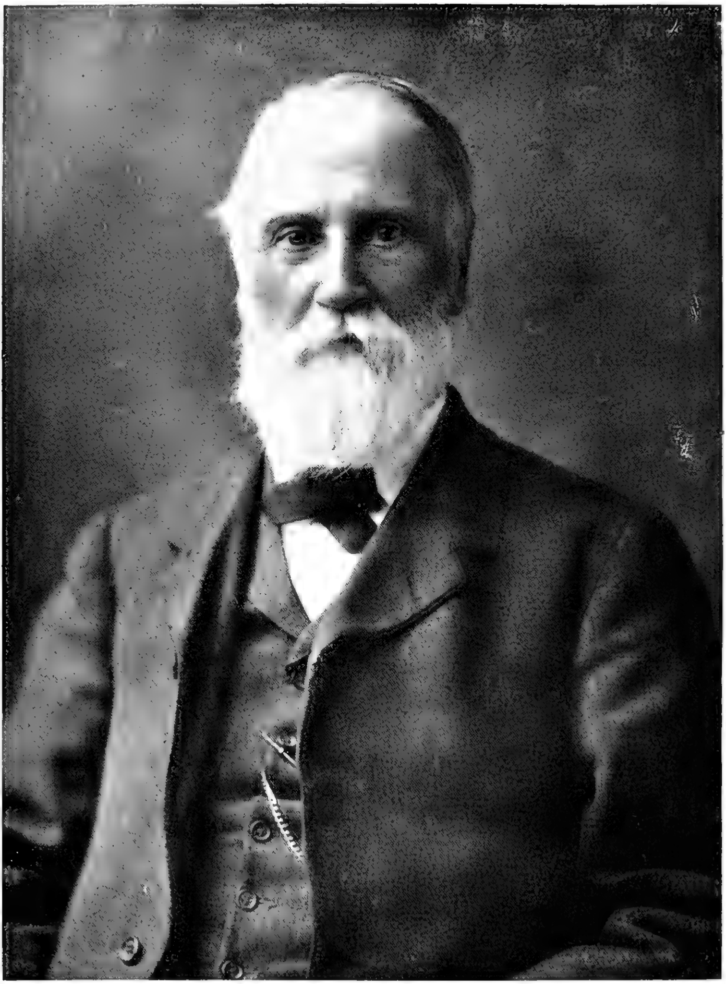


William Carruthers

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. V.—MAY, 1912.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

William Carruthers, Hon. Phil. Dr. et A.M. (Upsala), F.R.S., F.L.S., F.G.S., F.R.M.S., F.R. Phys. Soc. et Bot. Soc. Edinb., Corr. Memb. Acad. N. Sci. Philad., etc.

(WITH A PORTRAIT,[1] PLATE X.)

If we review the progress of any one of the natural sciences we shall find it is but the outcome of the genius and labours of many individual workers, who have devoted themselves for years to some particular branch of discovery or research. Taking palæobotany as an illustration, we may cite the name of William Carruthers as a striking example of an individual worker in that field, who, during more than a quarter of a century, specially devoted himself to the investigation and description of fossil plants, and has thus added largely to a knowledge of this section of the science of palæontology.

Born at Moffat, Dumfriesshire, on May 29, 1830, William Carruthers received his early education at Moffat Academy. Thence he proceeded, in 1845, to the University of Edinburgh. During two periods his regular course of studies was interrupted that he might hold tutorial posts, so that his University career was not completed until the spring of 1854. In the autumn of that year he was entered at New College, Edinburgh, with a view to study for the ministry of the Presbyterian Church. Here, under the teaching of Dr. John Fleming, the Professor of Natural Science, a man of conspicuous attainments as a naturalist, the inclination which Carruthers had already shown for science was strongly developed.

Acting under the advice and encouragement of Professor Fleming, who was then an old man, he devoted his energies to science with a view to becoming his colleague and successor. He accordingly studied in the University under Goodsir, Allman, and Balfour; but in 1858, before Carruthers' curriculum was finished, Professor Fleming died, and it was of course out of the question to appoint a student to the chair. It is interesting to note that forty-five years later Mr. Carruthers filled the chair for a year during a vacancy caused by the resignation of Professor Duns.

[1] This portrait, with some extracts from the text (by "S. W. C."), is reproduced from the Journal of the Royal Agricultural Society of England, vol. lxx, pp. 1–12, 1909, by kind permission of the Council.

His first position after leaving New College was that of Lecturer on Botany in the New Veterinary College, Edinburgh. A few months later he became Assistant to the Secretary of the Royal Society of Edinburgh, and in this capacity made the acquaintance of Dr. Robert Chambers, the publisher, which led later to his contributing the geological articles to the first edition of *Chambers' Encyclopædia.* William Carruthers' earliest scientific paper, recorded in the Royal Society's Catalogue, was a geological one on the Graptolites found in the rocks of his native county (Dumfriesshire), published in the Transactions of the Royal Physical Society of Edinburgh.

In 1859 he was offered, through Professor J. Hutton Balfour, the post of Assistant in the Department of Botany in the British Museum, and took up his duties there in August of that year, the staff of the Department at that time consisting of his chief (Mr. John Joseph Bennett) and himself. He thus definitely abandoned the Church as a profession, and devoted himself to science, but it was from no lack of sympathy with the Church, for throughout his life his great hobby has been Church history and theological literature.

In 1870 he was earnestly invited by Professor Asa Gray, the famous American botanist, to join him at Cambridge, Mass., with a view to his designating him as his successor. Mr. Carruthers was much drawn by this offer, but eventually decided not to give up his post in the Museum; indeed, in 1871 Mr. Bennett retired and Mr. Carruthers succeeded him as Keeper of Botany.

His first important studies in geology led him to undertake the careful investigation of the Graptolites of the Moffat Shales, and for some years he devoted his special attention to this group of organisms, in which Professor Lapworth, H. A. Nicholson, John Hopkinson, and others also laboured.

In the British Museum he had under his immediate charge a large and valuable series of fossil plants, mostly showing structure, being a part of the collection of the celebrated botanist Robert Brown, the first Keeper of the Botanical Department (1827), who died in London, June 10, 1858, the year before Carruthers entered the Museum. He also made good use of the fossil plants preserved in the Geological Department, to which he had free access. His first important paper related to the fructification of *Lepidodendron*, material for which he found in the Robert Brown Collection and in the Geological Department. He not only described the fossil spore-bearing cones of (*a*) *Lepidostrobus Brownii* and *L. ornatus*, and of (*b*) *Flemingites gracilis*, but he further showed that the presence of these shed spores was characteristic of, and made up entirely, a number of beds of coal as the 'splint-coal', the Fordel-coal, the 'parrot', the 'cherry', and cannel coals, as first noticed by Witham, Fleming, Prestwich, Morris, and other early observers, and he was thus able to connect them with the spore-bearing cones of *Lepidodendron*, which he figured in detail and accurately described (Geol. Mag., 1865, pp. 433–40, Pl. XII).

Apart from the purely systematic and descriptive papers on palæobotanical subjects, of which a list is given at the end of this notice, one of the most valuable and instructive contributions to fossil botany, from a student's and intellectual observer's point of view, was given by Mr. Carruthers in his historic lecture at the Royal Institution on Friday, April 16, 1869, on "The Cryptogamic Forests of the Coal Period", printed in this Magazine (Geol. Mag., Vol. VI, pp. 289–300, 1869).

In it we have a clear and concise description of the vegetation of certainly the most wonderful period of plant-development known in the past ages of our earth, and the author points to the remarkable fact that the vast stores of carbonized plant-remains on which human progress, arts, manufactures, and commerce now depend, were derived from the accumulated growth, not of the highly specialized forms of plant-life which chiefly characterize our present flora, but from humble vascular Cryptogams, Ferns, Equisetaceæ, Lycopodiaceæ, and 'Pill-worts' (Marsiliaceæ), many of which (as the 'Club-mosses' and 'Horse-tails') attained to giant growths and formed veritable forests, which for ages incalculable must have flourished (homotaxially, if not synchronously) over nearly the whole earth.

This chapter of the past, written by such an expert as Mr. Carruthers, needs but to be repeated by similar Evangels for every other geological stage to make our earth's past history a veritable fairy tale of delightful literature for all.

From 1871 to 1880—when the removal of the Natural History Collections to Cromwell Road took place—the restricted space occupied by the exhibited Botanical Series and the Herbarium itself, at Bloomsbury, precluded the possibility of any great expansion or proper display, and the very life of the Department itself was threatened also by a powerful attempt to capture the Museum Collection and transfer it to Kew. But Mr. Carruthers' evidence before the Royal Commission on Scientific Instruction made so clear a case for the existence of the botanical collections as a part of the great Natural History Collections, in our National Museum in London, as to fully justify and firmly secure its continuance.

When the removal to South Kensington was effected in 1880, adequate space was allotted to the Botanical Department, and the work of re-arranging both the public exhibits and the collections for the use of students owed much to Mr. Carruthers' talent for organization.

In labelling and illustrating the specimens in the public collections, moreover, he was one of the pioneers of the system of giving adequate explanations on the labels, thus making the collections far more interesting and instructive to the public.

The removal to South Kensington necessitated the creation of a Departmental Library, for which a special grant was made. This task occupied Mr. Carruthers for some years, resulting in the formation of what has now become the finest botanical library in the world.

In 1870 the Linnean Society published Mr. Carruthers' very important monograph "On the Fossil Cycadean Stems from the Secondary Rocks of Britain" (Trans. Linn. Soc., vol. xxvi, pp. 675–708, with ten plates, 1870, 4to). In this work one realizes the advantage of the author having an accurate knowledge of recent plants, both structural and physiological, thus giving to his published opinions on the plant-remains found embedded in the various strata a far greater value and scientific importance.

In 1871 William Carruthers obtained the honour of election to the Royal Society, on the Council of which he served (1877–9). In 1871 he was appointed Consulting Botanist to the Royal Agricultural Society of England, a post which he held with distinction for thirty-nine years.

In 1884 he attended the meeting of the British Association in Montreal and took a long trip in America (in company with the late Mr. Charles de Laune Faunce de Laune and Mr. F. S. W. Cornwallis), in the course of which he secured interesting specimens for his Department, and got into closer touch with museums and herbaria on the American continent. He and his fellow-travellers also gathered much valuable experience in agricultural botany on this expedition.

In 1886 he was President of the Biological Section of the British Association, at its Birmingham meeting, and there delivered an address on the persistence of specific characters in plants, which presented so difficult a problem to the supporters of the Darwinian theory that it remains unanswered to this day.

From 1886 to 1890 Mr. Carruthers was chosen to be President of the Linnean Society, in which period its centenary celebrations fell; and for organizing and carrying through these important commemorations he received the Society's thanks. The Linnean Medal was then founded, and he had the pleasure of presenting the first medals to Sir Richard Owen and Sir Joseph Hooker. In 1907 Mr. Carruthers was sent by this Society to Sweden as its representative at the bicentenary commemorations of the birth of Linné, and at that time the ancient University of Upsala conferred on him the honorary degrees of M.A. and Ph.D. He had also been elected President of the Geologists' Association 1875–7, and of the Royal Microscopical Society 1900–1. He retired from the Keepership of Botany in the British Museum (Nat. Hist.), under the age clause, in 1895, when the scientific staff consisted of the keeper and five assistants.

The number of papers published by Mr. Carruthers upon recent botanical subjects (especially in connexion with Economic Botany for the Royal Agricultural Society) amounts to considerably over 100. Those enumerated in the annexed list relate to palæontological and geological subjects only.

His care in attention to detail, without losing sight of salient points, his power of lucid exposition of a subject, and his willingness to satisfy any genuine desire for knowledge have made him a most useful officer both to the British Museum and the Royal Agricultural Society of England.

Speaking of William Carruthers' personal character the writer has ever found him, during forty years association, a most consistent and true friend and a staunch and faithful colleague. Like many of his countrymen from across the Tweed he was a good fighter, and when he had made up his mind that his cause was a just one he was very tenacious in maintaining his ground. Had he lived in the old days he would certainly have been a good fighting Covenanter. His list of honours is a long one, but are they not all duly recorded in the Year Book of the Royal Society for 1912, p. 8?

In 1865 he married Jane Couch, eldest daughter of William L. Moffatt, Architect, Edinburgh, and has two sons and a daughter. His second son, John Bennett, followed his father's footsteps, and took up Economic Botany. After acting as assistant in his father's laboratory and giving special attention to the diseases of plants, he went to Ceylon at the request of the planters to investigate a malady destroying the Cacao trees. Thereafter he entered the Colonial Service and did excellent pioneer work in Ceylon, the Federated Malay States, and Trinidad, where he died in 1910 at the early age of 41. The elder son, Samuel William, who has an honours M.D. of Edinburgh, is in practice at Norwood, and his daughter has her home in the same suburb.

He is now enjoying with his family near him, at Central Hill, Norwood, the repose of a long, useful, and honourable life.

List of Contributions to Palæontology, etc., by Dr. William Carruthers, F.R.S.

1858. "Dumfriesshire Graptolites, with descriptions of three new species": Proc. Phys. Soc. Edinburgh, vol. i, pp. 466–70; [republished in] Ann. Mag. Nat. Hist., vol. iii, pp. 23–6, 1859.

1862. "The Geology of Moffat": Proc. Phys. Soc. Edinburgh, vol. ii, pp. 383–90; Edinburgh New Phil. Journ., vol. xvi, pp. 33–40.

"On a section at Junction Road, Leith": Quart. Journ. Geol. Soc., vol. xviii, pp. 450–3.

1865. "On an undescribed Cone from the Carboniferous beds of Airdree, Lanarkshire: *Flemingites gracilis*": Geol. Mag., Vol. II, pp. 433–40, Pl. XII.

"On *Caulopteris punctata*, Goepp., a tree-fern from the Upper Greensand of Shaftesbury in Dorsetshire": ibid., pp. 484–7.

1866. "On the Vegetation of the Coal Period": ibid., Vol. III, pp. 229–30.

"On Araucarian Cones from the Secondary beds of Britain": ibid., pp. 249–52.

"On some fossil Coniferous fruits": ibid., pp. 534–46.

"On the structure and affinities of *Lepidodendron* and *Calamites*": Trans. Bot. Soc. Edinburgh, vol. viii, pp. 495–507; Journ. Bot., vol. iv, pp. 337–48.

1867. "On Gymnospermatous fruits from the Secondary rocks of Britain": Journ. Bot., vol. v, pp. 1–21.

"On Calamiteæ and fossil Equisetaceæ": ibid., p. 304.

"On the structure of the fruit of *Calamites*": ibid., pp. 349–56.

"Note on the systematic position of Graptolites and on their supposed ovaria-vesicles": Geol. Mag., Vol. IV, pp. 70–2, 187, 336.

"On some Cycadean fruits from the Secondary rocks of Britain": ibid., pp. 101–6.

"On an Aroideous fruit from the Stonesfield Slate": ibid., pp. 146–7.

"On *Cycadoidea Yatesii*, a fossil Cycadean stem from the Potton Sands, Bedfordshire": ibid., pp. 199–201.

Appendix D, on Graptolites, in Sir R. I. Murchison, *Siluria* [London].

"Graptolites, their structure and systematic position": *Intellectual Observer*, vol. xi, pp. 283–92, 365–74.

"On British Fossil Cycadeæ": Journ. Bot., vol. v, pp. 302–4; Rep. Brit. Assoc. Adv. Sci. (Dundee, 1867) [1868], p. 80.

"Enumeration of British Graptolites": ibid., p. 57.

"On the fruit of a *Pandanus* from the Great Oolite": Journ. Bot., vol. v, p. 304. [Abstract of paper read before Dundee Meeting, Brit. Assoc.]

1868. "A Revision of the British Graptolites, with descriptions of the new species and notes on their affinities": GEOL. MAG., Vol. V, pp. 64–74, 125–33.

"British Fossil Pandaneæ": ibid., pp. 153–6.

"Classification of Graptolites": ibid., pp. 199–200 [letter to Editor].

1869. "On some undescribed Coniferous fruits from the Secondary rocks of Britain": ibid, Vol. VI, pp. 1–7.

"On *Beania*, a new genus of Cycadean fruit, from the Yorkshire Oolites": ibid., pp. 97–9.

"On the plant remains from the Brazilian coal beds, with remarks on the genus *Flemingites*": ibid., pp. 151–6.

"On the plant remains found in the Cretaceous and Tertiary strata of N. America": Journ. Bot., vol. vii, 82–5.

"On the genus *Knorria*, Sternberg": ibid., pp. 153–5.

"On the structure and affinities of *Sigillaria* and allied genera": Quart. Journ. Geol. Soc., vol. xxv, pp. 248–54, pl. x; Phil. Mag., vol. xxxviii, p. 402.

"Age of the Rocks of Alaska Territory": GEOL. MAG., Vol. VI, p. 239 [letter to Editor].

"The Cryptogamic forests of the Coal Period": ibid., pp. 289–300; Proc. Royal Institution, vol. v, pp. 511–22.

1869 70. "On the structure of the stems of the Arborescent Lycopodiaceæ of the Coal Measures": Monthly Micros. Journ., vol. ii (1869), pp. 177–81, 225–7; vol. iii (1870), pp. 144–54.

"On Reptilian Eggs from Secondary Strata"; "On Slickensides": Notice of papers read at Exeter Meeting (1869), Brit. Assoc. Adv. Sci., Rep. p. 86 [1870].

1870. "Review of the contributions to Fossil Botany published in Britain in 1869": GEOL. MAG., Vol. VII, pp. 181–4.

"On the Petrified Forests near Cairo": ibid., pp. 306–10, Pl. XIV.

"On the structure of a fern stem from the Lower Eocene of Herne Bay, and its allies, recent and fossil": Q.J.G.S., vol. xxvi, pp. 349–53, pls. xxiv, xxv; Phil. Mag., vol. xl, pp. 225, 226.

"On the nature of the scars in the stems of *Ulodendron*, *Bothrodendron*, and *Megaphyllum*, with a synopsis of the species found in Britain": Monthly Micros. Journ., vol. iii, pp. 144 et seq.

"On fossil Cycadean stems from the Secondary rocks of Britain": Trans. Linn. Soc., vol. xxvi, pp. 675–708, with ten plates, 4to.

"On the history and affinities of the British Coniferæ": Rep. Brit. Assoc. Adv. Sci. (Liverpool, 1870) [1871], p. 71.

"On the Sporangia of Ferns from the Coal-measures": ibid.

"Remarks on the fossils from the railway section at Hoyton": ibid., pp. 71–2.

"Note on an *Antholithes* discovered by C. W. Peach": ibid., p. 72. [Abstract.]

1871. "On the vegetable contents of masses of limestone occurring in Trappean rocks in Fifeshire, and the conditions under which they are preserved": Rep. Brit. Assoc. Adv. Sci. (1871), pp. 94–5.

"Review and Synopsis of the contributions to Fossil Botany published in Britain in 1870": GEOL. MAG., Vol. VIII, pp. 218–20.

"On two undescribed Coniferous fruits from the Secondary rocks of Britain: *Pinites hexagonus*, *Sequoiites ovalis*": ibid., pp. 540–4.

"On some vegetable structures recently discovered in the Lower Coal-beds at Halifax, 1870": Rep. Croydon Micros. Club, vol. i, pp. 26–7.

"On some supposed Vegetable Fossils": Q.J.G.S., vol. xxvii, pp. 443–8, pl. xix.

1872. "On the leaf-bearing species of *Lepidodendron*": Monthly Micros. Journ., vol. vii, pp. 50–4.

"On the history, histological structure, and affinities of *Nematophycus Logani*, Carr. (*Prototaxites Logani*, Dawson), an alga of Devonian age": ibid., vol. viii, pp. 160–72, pls. xxxi–ii.

"On *Traquairia*, a Radiolarian Rhizopod from the Coal-measures": Rep. Brit. Assoc. Adv. Sci., 1872, p. 126; Quart. Journ. Micros. Sci., vol. xii, pp. 397–8.

"Note on some supposed fragments of a *Eurypterus*": in Dr. H. Woodward's *British Fossil Crustacea—Merostomata* (Mon. Pal. Soc.), pp. 168–71.

"Notes on some Fossil Plants from Queensland, Australia": Q.J.G.S., vol. xxviii, pp. 350–60. Appendix II in R. Daintree, *Notes on the Geology of the Colony of Queensland.*

"Notes on some Fossil Plants": GEOL. MAG., Vol. IX, pp. 49–59, Pl. II.

"Review of the contributions to Fossil Botany published in Britain in 1871": ibid., pp. 369–73.

1872–3. "On the Tree Ferns of the Coal Measures, and their affinities with existing forms": Rep. Brit. Assoc. Adv. Sci., 1872 [1873], pp. 98–9; GEOL. MAG., Vol. IX, pp. 465–7; Journ. Bot., vol. vii, pp. 279–81, 1872; Q.J.G.S., vol. xxix, pp. 380–1.

1873. "On *Halonia* of Lindley & Hutton and *Cyclocladia* of Goldenburg": GEOL. MAG., Vol. X, pp. 146–52, Pl. VII.

"Review of the contributions to Fossil Botany published in Britain in 1872": ibid., pp. 461–5.

"*Nematophycus* or *Prototaxites*?": Monthly Micros. Journ., vol. x, pp. 208–10.

"On the Tree Ferns of the Coal Measures, and their relations to other living and fossil forms": Q.J.G.S., vol. xxix, p. 380. [Abstract.]

"On some Lycopodiaceous plants from the Old Red Sandstone of the North of Scotland": Journ. Bot., vol. ii, pp. 321–7.

1876. "On the Flora of the London Clay of Sheppey": Proc. Geol. Assoc., vol. iv, pp. 318–19.

"Note on the Flora of the Gault, with description of a new pine cone, *Pinites Pricei*": ibid., pp. 278–81.

1876–8. ["Fossil Plants"] Presidential Address to Geologists' Association, November 1875: ibid., vol. v, 1876–8, pp. 1–16.

["Evolution of Plant Life"] Presidential Address to the Geologists' Association, November, 1876: ibid., pp. 17–35; GEOL. MAG., 1876, pp. 560–5.

1877. "Description of a new species of *Araucarites* from the Coralline Oolite of Malton" [in Blake & Hudlestone]: Q.J.G.S., vol. xxxiii, p. 402.

1878. "Descriptions of Tertiary Plant-remains from Bracklesham and Worthing, Sussex"; "The Plant-remains of the Upper and Lower Cretaceous (Neocomian) Formations in England": in F. Dixon, *The Geology of Sussex*, new [second] edition, 1878.

1879. "Note on Mr. Lee's specimens of fossil wood from Griqualand": GEOL. MAG., Vol. VI, p. 286 [letter to Editor].

1880. "On a collection of Fossils from the Bowen River Coal-field, etc.": [in Etheridge] Proc. R. Phys. Soc. Edinburgh, vol. v, p. 325.

1882. "Contributions to the Palæobotany of Sweden": GEOL. MAG., Vol. IX, pp. 22–4.

1883. "On the foliage of *Sigillaria Serlii*, Brongn.": ibid., Vol. X, pp. 49–50.

1884. "Coal, and the Plants which form it": Ann. Rep. Dulwich Coll. Sci. Soc., 1883–4, pp. 39–41.

1885. "Notes on Fossil Roots in the Sarsen Stones in Wiltshire": GEOL. MAG., Ser. III, Vol. II, pp. 361–2.

II.—Sedgwick Museum Notes.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XI.)

Dionide atra, Salter. (Pl. XI, Figs. 1–6.)

In 1866 Salter[1] established this species on the basis of two somewhat distorted pygidia, but the head-shield and thorax have remained undescribed and apparently unknown. The discovery therefore by Mr. V. M. Turnbull of some complete though somewhat imperfectly preserved individuals in the Arenig Beds near Haverfordwest is of not a little interest; and with the aid of several detached head-shields, in addition to those belonging to individuals with typical pygidia, we are able to give a fairly complete description of the species, which, owing to its relations to other genera, is particularly worthy of note.

Description. Head-shield semicircular or semi-elliptical, gently convex, with genal angles produced broadly backward and pointed. Border narrow, smooth, widest in front, narrowing posteriorly on each side, separated from rest of head-shield by narrow marginal furrow in which lies a single row of equidistant and equal elongated pits.

Cheeks gently convex, divided into (1) an outer circumferential region, and (2) an inner triangular region on each side of glabella, and connected in front of it by a narrow band. Circumferential region produced back into genal prolongations; marked off from inner region by possessing a slight independent convexity and by a different ornamentation; internally defined by three concave curves, two lateral and one median, meeting on each side in obtuse angles a little behind anterior end of glabella; median part of circumferential region of uniform width; lateral parts widest at obtuse angles of junction, and sharply bounded behind by fine raised vascular trunk running backwards towards genal angles. Surface of circumferential region marked by radiating sinuous branching and anastomosing fine thread-like lines interspersed with minute pits, the radial arrangement of the lines becoming less apparent towards genal angles.

Inner regions of cheeks with straight posterior edge furnished with narrow pleuro-occipital segment marked off by strong furrow, each inner region thus forming a quarter of a circle, and connected in front of the obtuse angles of circumferential region by narrow pre-glabellar band of uniform width surrounding anterior end of glabella. Surface of inner region of cheeks crossed diagonally by gently curved strong line ('cheek-line') starting from middle of side of glabella and running outwards and backwards to meet inner edge of circumferential region a little in front of inner angle of genal prolongations, with traces of small 'ocular' tubercle on it at about the middle of the cheek; very minute punctæ and extremely delicate striæ present over whole surface.

Glabella oval, slightly angulated at front end, produced behind into short blunt median spine, moderately convex, about two-thirds the length of the head-shield; small elongated median tubercle present,

[1] Salter, Mem. Geol. Surv., vol. iii, p. 321, pl. xi *a*, figs. 9, 9*a*.

and traces of a pair of small depressed triangular basal lobes at sides of median spinose prolongation. Surface of glabella ornamented like inner region of cheeks.

Axial furrows united in front of glabella, with small pit at front end on each side.

Thorax imperfectly known; axis as wide as glabella, cylindrical; pleuræ horizontally extended, straight, of uniform width, with fine diagonal furrow and obliquely truncate ends (?).

Pygidium parabolic, flattened, nearly as long as wide; axis conical, elongated, about one-fifth the width of pygidium in front, tapering to blunt end not quite reaching posterior margin of pygidium, completely annulated to tip by 20–24 well-defined rings, of which the anterior ones have the interannular furrows trilobate, being arched forward in the middle and at the sides. Lateral lobes horizontal, nearly flat, composed of 15–17 well-marked straight radiating pleuræ, widening outwards but ending a short distance inside the margin (the last 5–6 pleuræ arch slightly backwards and become subparallel); each pleura marked by fine submedian slightly diagonal furrow reaching nearly to extremity. No border present.

Surface of thorax and pygidium very minutely punctate.

Dimensions.

		mm.
Length of head-shield . . .	about	7·5
Width of head-shield . . .	,,	15·0
Length of pygidium	,,	6·5
Width of pygidium	,,	7·5

Horizon and Localities. Upper Arenig: Ty Obry, Portmadoc (Salter's types); Long Plantation Cutting, near Scolton, Haverfordwest (Turnbull's specimens).

Remarks. The pygidium of this trilobite as represented by Mr. Turnbull's specimens is certainly identical with that described and figured by Salter[1] as *Dionide atra* from Ty Obry, Portmadoc; but the two type-specimens are distorted, one being laterally compressed and therefore unduly elongate in appearance (Salter, op. cit., fig. 9), and the other being unnaturally broadened out transversely (Salter, op. cit., fig. 9*a*). In the latter specimen the inner surface is exposed and a narrow doublure of uniform width is therefore visible. In the elongated specimen (here figured) the axis shows 20–22 rings and over 20 pleuræ are present on the lateral lobes, while in the other about 16–20 pleuræ can be counted. Salter seems to have been incorrect in stating that the pleuræ are interlined (=furrowed) for only their first half and that the furrows bend back abruptly, but the mistake arose from the poor preservation of the types.

The head-shield and thorax of this species have been hitherto unknown, and it is satisfactory to find them now in attachment to the pygidium. The isolated head-shields are better preserved than the more complete specimens, though those belonging to the two individuals possessing much of the rest of the body show the characters with quite sufficient distinctness. The structural characters of this

[1] Salter, Mem. Geol. Surv., vol. iii, p. 321, pl. xi*a*, figs. 9, 9*a*.

species are interesting, for the division of the cheeks into two distinct regions recalls the features of the 'cheek-roll' and 'cheek-lobes' of many species of *Harpes*, as carefully described by Bather[1] in the case of *H. bucco*. The marginal row of pits suggests a comparison with that found at the base of the cheek-roll and inner margin of the 'brim' in many species of that genus, and the 'cheek-line' with that in *H. vittatus*, Barr. The distinctive ornamentation of the outer and inner portions of the cheeks is also commonly met with in *Harpes* and *Harpides*, but not in *Dionide*. With regard to *Erinnys*, as defined by Grönwall,[2] we may note the similarity of the main vascular trunk running backwards and outwards with radial branches arising from it, especially on the anterior side, and in *E. breviceps* (Angelin) there is a somewhat similar row of marginal pits.

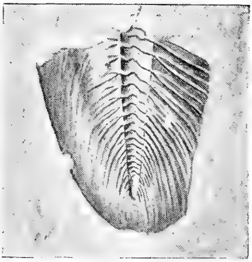
But the reference to the genus *Dionide* seems beyond dispute on the strength of the large size, many annulations, and other characters of the pygidium which may be compared[3] with that of *D. lapworthi* (Eth. & Nich.), *D. formosa*, Barr., and *D. euglypta*, Angelin. The many points of affinity possessed by the head-shield with other genera indicate the intimate relations of *Dionide* with *Harpes*, *Harpides*, and *Erinnys*.

In 1875 Hicks[4] described and figured a trilobite from the Upper Arenig of the St. David's area as *Trinucleus Ramsayi*. The material was very poor and fragmentary, but a comparison of the types with the head-shields of *D. atra* leads me to believe that they are identical, and if so Hicks' name must be dropped. The imperfect head-shields on which Hicks based his species show the single marginal row of pits, the radially ornamented circumferential region of the cheeks, the pre-glabellar band of the inner region, the 'cheek-line', the main vascular trunk, and the general shape and contour of *D. atra*, so far as their fragmentary condition allows us to determine. The only difference is the rather coarser ornament of the 'cheek-lobes', though it is likewise very much finer and quite different from that of the 'fringe' (=circumferential region). The greater coarseness seems probably due to the state and method of preservation of the specimens and to the larger size of the individuals which Hicks figured. No other feature of importance is present by which we can separate them, and the St. David's *Trinucleus Ramsayi* must undoubtedly be referred to the genus *Dionide*, and almost certainly to Salter's species. Fearnsides[5] has mentioned a *Dionide* "closely similar to the *D. atra* of Ty Obry" as occurring in the Olchfa or *bifidus* Shales of the Arenig fawr district.

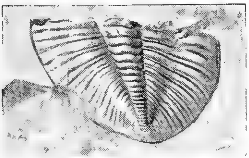
EXPLANATION OF PLATE XI.

FIG. 1. *Dionide atra*, Salter. Pygidium, elongated and distorted. Ty Obry, Portmadoc. (Probably the specimen figured by Salter, Mem. Geol. Surv., iii, pl. xi*a*, fig. 9.) × 2.

[1] Bather, "*Harpes bucco*": Rivista Ital. Paleont., xv, pp. 116–20, 1910.
[2] Grönwall, "Bornholms Paradoxideslag": (Danmarks geol. Undersog., ii, Nr. 13), 1902, pp. 94–98.
[3] Reed, Mon. Girvan Trilob. (Palæont. Soc.), 1903, pt. i, p. 26.
[4] Hicks, Quart. Journ. Geol. Soc., vol. xxxi, p. 183, pl. x, figs. 1, 2, 1875.
[5] Fearnsides, ibid., vol. lxi, p. 623, 1905.

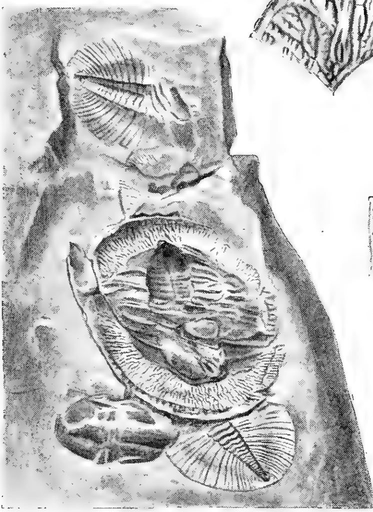
1


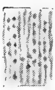

3

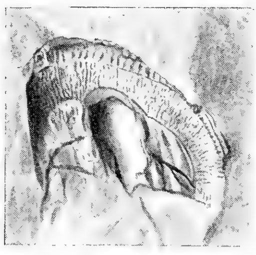
2 *a*


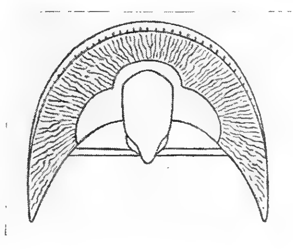

3 *a*

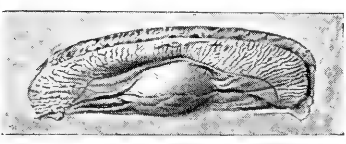

4

2



4 *b*


4 *a*


6

5


T. A. Brock del.

Fig. 1. *Dionide atra*, Salter, 1866. Upper Arenig: Portmadoc.
Figs. 2–6. Ditto. Upper Arenig: near Haverfordwest.

FIG. 2. *Dionide atra*, Salter. Group of portions of two individuals, broken and displaced, showing external impression of parts of head-shields, fragments of thorax, and the two pygidia. Upper Arenig Series: Long Plantation Cutting, near Scolton, Haverfordwest. × 2.
,, 2*a*. Ditto. One of the pygidia. × 3.
,, 3. Ditto. Head-shield of another individual with part of thorax attached. Same horizon and locality. × 4.
,, 3*a*. Ditto. Portion of circumferential region of same specimen. × 8.
,, 4. Ditto. Head-shield, showing border. Same horizon and locality. × 3.
,, 4*a*. Ditto. Impression of same specimen. × 3.
,, 4*b*. Ditto. Portion of cheek of same specimen showing ornamentation. × 8.
,, 5. Ditto. Head-shield, transversely distorted. Same horizon and locality. × 3.
,, 6. Ditto. Diagrammatic restoration of head-shield.

III.—On the Geology of Venezuela.

By Leonard V. Dalton, B.Sc. (Lond.), F.G.S.

I. Introductory.

ALTHOUGH the Republic of Venezuela adjoins two British colonies, only some three or four papers have been published in English journals dealing with the geology of the country. These, moreover, are concerned with local observations, and no attempt at correlation has been made. A considerable mass of material is available in Continental publications, and the author, during a series of journeys through Northern Venezuela in 1910, was able to collect sufficient data to form a fairly clear idea of the succession of deposits, and to roughly correlate the views of different writers. While more compilatory than original, the following paper is offered as a basis for further study of the geology of an area so closely connected with the colonies of British Guiana and Trinidad, and the short bibliography includes all those papers bearing directly on the subject which are known to the author.

From a geological point of view there are two distinct areas in Venezuela between which there are few points of resemblance in general character, namely, the area south of the Orinoco, commonly known as Guayana, or the Guayana Highlands, and Northern Venezuela. In the first we have an ancient, extremely stable, land-surface, which has undergone few changes since the dawn of geological history, and none at all in recent periods; north of it lies an area which has been the scene of great geological changes down to quite recent times, and where numerous earthquakes still testify to lack of equilibrium in the region. Since the rocks of the south are all of greater antiquity than any of those constituting the region north of the Orinoco, the whole series of deposits will be briefly described in order, beginning with the most ancient, while the various igneous rocks will be mentioned along with their associated sedimentaries.

II. Succession of Deposits.

Wherever travellers have collected data in the Guayana region they report a foundation of granite, gneiss, schist, or similar rock, and where, as in the gold-bearing region of Yuruari, these observations can be linked on with the fuller and more scientific records of British Guiana, there is evidence that the lowest rocks over the whole area form a complex of ancient igneous or highly metamorphosed sedimentary deposits, similar in petrological character, both macro- and microscopically, to the oldest rocks of other parts of the globe, and notably to the Lewisian complex of the Scottish Highlands. It seems justifiable therefore to consider them, provisionally at least, as of Archæan or pre-Cambrian age, and as representing some of the most ancient parts of the solid crust of the globe.

These Archæan rocks occur, as has been stated, over the whole Guayana region, constituting hills in some parts, but generally forming the more or less level platform from which the more notable elevations rise. South of Ciudad Bolivar, where they have been studied in most detail, they include gneisses, hornblende schists, and granites, all containing evidence of great antiquity in geological time. Traversing these are two series of dykes, or intrusions in other form of igneous rocks, one ancient, the other, as will be seen, of later date. The older series consists of acidic material, mainly quartz-porphyrites and felsites, which, with the surrounding rocks, have undergone considerable dynamic or regional metamorphism. Traversing these, in belts which have a general N.W.–S.E. strike, are dykes and sills of basic material, including basalts and dolerites; along these intrusions, particularly near their intersection with the older series, the majority of the mineral veins are found.

The basal complex everywhere consists of the original gneisses, etc., and the acidic intrusives, while, resting upon these at very many points in Guayana, are red and white sandstones and coarse conglomerates, with a few bands of red shale, in a series about 2,000 feet thick. All the materials of this series of beds appear to have been derived directly from the gneisses; the strata are practically horizontal and have suffered little fracturing, save where they are traversed by the basic intrusives already referred to, which are thus shown to be of much later date than the acidic rocks. From analogy with Brazil it may be inferred that the basalts, etc., are of Secondary age; in the sandstone groups the sills frequently expand into laccoliths, and in British Guiana it is found that the protection afforded to the sedimentaries under the intrusions of igneous rock has caused them to remain after the denudation of the surrounding areas, forming peculiar flat-topped mountains with vertical cliffs on every side. Whether all the peculiar elevations of this type, so characteristic of Guayana, are due to igneous intrusions is a point upon which we may one day be enlightened. Certain it is that the Sierra Pacaraima, and the vertical-sided outliers north of it, are composed, for the greater part, of these horizontal sandstones. Mount Roraima gives the best known section of these rocks, and *Roraima Series* would seem a fitting name for them.

No fossils are known to occur in the rocks of the Roraima Series, but since they are traversed by Mesozoic intrusives they must be assumed to belong at latest to the early part of that period; while from their constitutional resemblance to the Torridonian Sandstone of the Scottish Highlands, and exactly similar relation to the Archæan complex below, it may be reasoned that they should be considered as equivalent in age, and therefore forming, with the Guayana complex, the most ancient rocks in Venezuela.

North of the Orinoco we have in the Caribbean Hills and elsewhere a series of gneissose and schistose rocks, named by Wall in 1860 the *Caribbean Series*. The group includes silvery mica-schists (not infrequently mistaken for gold or silver ores), graphitic schists and gneisses with banding of all degrees of fineness, whilst, in addition, crystalline limestones occur in Eastern Venezuela. The thickness of the group is not known with any certainty, but Mr. E. H. C. Craig estimated it at less than 2,000 feet in Trinidad, though, owing to crushing and complicated folding, the apparent thickness is much greater. The age of these strata is unknown, but they generally show distinct evidence of a sedimentary origin, notwithstanding that some of the gneisses may be altered igneous (plutonic) rocks; the relation of the Cretaceous of Venezuela to them shows that they are at least early Mesozoic, and may be Palæozoic, or even Archæan, while it is very possible that parts of the Andes are older than the strata exposed in the Caribbean Hills.

The series was suitably named by Wall, as the main range of the Caribbean Hills is everywhere formed of these metamorphics, but they occur also in Margarita and throughout the Andes, while in the Llanos north of El Baul is an elevated area (known as *la Galera*) with numerous hills of similar rocks.

Next in age appear to be a group of red and yellow quartzites and sandstones with varicoloured shales and slates, and a few black bituminous limestones, often somewhat metamorphosed. These rocks cover practically the whole of the elevated region round Barquisimeto or Nueva Segovia (the Segovia Highlands), and the author therefore suggests the name *Segovia Group* for them. From several localities fossils (Ammonites, *Inoceramus*, etc.) have been obtained in them, notably near Tocuyo (by Karsten) and in the Sierra de Perija (Sievers), which show their age to range from Neocomian to Aptian (Lower Cretaceous).

In addition to their great development in the Segovia Highlands the rocks constitute a great part of the Serrania Interior, both in the Caracas and Cumaná regions, and form both flanks of the Cordillera of Merida, as well as part of the Sierra de Perija.

Above the Segovia Group in scattered areas throughout the Cordilleras there is a massive well-bedded limestone, with fossils indicating an age equivalent to the Turonian or Senonian of Europe. This limestone was studied by Dr. Sievers near Capacho in Tachira, and named by him the *Capacho Limestone*. It occurs frequently in the Cordillera of Merida, and is well seen to the east of Carache in the Humocaro Hills, where it forms castellate masses and high cliffs and gorges along the rivers. In the Segovia Highlands the Cordilleras of San Luis and Agua Negra include large masses of this limestone, and it occurs in the peninsula of Paraguana, but has been detected at only a few points in the Serrania Interior south of Caracas. In the Sierra de los Tageres it constitutes many of the ridges.

Along the western flank of the Cordillera of Merida, in the northern part of the Segovia Highlands, and throughout the Serrania Interior to the Gulf of Paria, there are belts of varying extent of a series of beds, mainly clays, with brown sandstone, carbonaceous shale, thin limestone, clay ironstone and pyrites, etc., which furnish fossils both of a high Cretaceous horizon and of Lower Tertiary age, the Cretaceous fauna being confined to the lower beds, while Nummulites and other Tertiary fossils are found in the higher strata. They are well seen in the Cerro de Oro (so called from the abundance of yellow pyrites, mistaken for gold) near Rubio in Tachira. Dr. Sievers therefore termed this group the *Cerro de Oro Series* (System). The age of the beds included under this name appears to range from Upper Senonian to Eocene, i.e. probably equivalent to other similar deposits known as Cretaceous in Trinidad.

The three geological divisions enumerated above would seem to be separated from each other only by short intervals of time, or by none at all, but there appears to be a greater difference in age between the Cerro de Oro Group and the next later series, which is markedly unconformable to all older rocks.

On the east side of the Lake of Maracaibo, and possibly on the west also, as well as on the Coro coast and over the peninsula of Paraguana, in some of the islands on the Cumaná coast, and under the Llanos, there is a series of calcareous sandstones and shales, often highly fossiliferous, which appear to correspond to the 'Newer Parian' of Trinidad. Fossils were collected from Cumaná by Mr. Wall and described by Mr. Guppy of Trinidad, between 1860 and 1870, which show the age of the beds to be probably Upper Miocene, so that our first scientific data in regard to them came from Cumaná; it seems fitting, therefore, to affix the name *Cumaná Series*.

Finally, there are two groups of strata widely different in character, but probably of the same age: one, the *Llano Deposits* (current-bedded clays and gravels surmounted by gravels), covering the whole of the great plains of Venezuela; the other a series of shell-beds with remains of mollusca little different from those now inhabiting the Caribbean Sea. These occur all round the coast from Coro eastwards, are well seen at Cabo Blanco, west of La Guaira, and form practically the whole of the island of Cubagua, whence the name *Cubagua Beds* is suggested for them. Both these groups may be taken to be of Pleistocene age, and with them should be classed the gravel and river deposits of the hills, with *Megatherium* and other mammalian remains, found near Tocuyo, the lake of Valencia, Mount Turumiquiri, and other points.

The *Recent Alluvium*, which covers so great an extent in the delta and round the lake of Maracaibo, needs no special remark.

Igneous rocks of the plutonic type also occur in Northern Venezuela, and the outcrops are in some cases of wide extent; thus, the Sierra Nevada and other regions of maximum elevation in the Venezuelan Andes are composed of a white granite, apparently of more recent date than the metamorphosed strata surrounding it. The same rock occurs under much of the peninsula of Paraguana, where there is also an intrusion of augite-porphyry in the Cerro de Santa

Ana. A rock of similar type covers a wide area in the hills south of Caracas, in the region of San Casimiro, apparently of Tertiary age, but this cannot at present be definitely stated.

III. Tectonics.

The main tectonic features of Venezuela are very simple. In the south we have the great Guayana massif, with, apparently, a general east and west strike varying to east-north-east, and with a boundary on the north side which is at right angles to the meridian. On the left bank of the Orinoco there lies the great synclinal basin of the Llanos, and beyond this again a continuous line of upheaval in the Cordilleras of the Andes and of the coast; here the strike changes, becoming approximately east and west in the Caribbean Hills, and north-east or north-north-east in the Andes, while in the intermediate highlands the strike varies from point to point. Beyond this the Maracaibo basin and the coastal plains of Coro represent a second synclinal area, while north and west of these the Sierra of Perija, the igneous masses of Goajira in Colombia, the granite and Cretaceous of Paraguana and Curaçao, and the metamorphics of Margarita, appear to mark a second anticlinal line on the northern limits of Venezuela. It will be seen that in general the structure-lines agree with the main physical divisions of the country: the upward movement which changed the Llanos region from a shallow partly-enclosed sea to broad low-lying plains was probably part of that which, beginning in the Middle Tertiary times, is still continuing to accentuate the folding of the Andes and to raise the Maracaibo region. The subsidiary movements and structure-lines have hardly been studied sufficiently to afford data for a detailed account of them.

IV. Earthquakes and Hot Springs.

While active volcanoes are entirely wanting in Venezuela, there is little lack of those evidences of internal energy so often associated with them. Earthquakes have been known in the northern part of the country from the time of the earliest settlements; thus Nueva Cadiz (on Cubagua) was shaken and the fortress of Cumaná demolished in 1530, and thirteen years later the city on Cubagua was utterly destroyed. Many shocks were experienced of greater or less violence throughout the seventeenth and eighteenth centuries, but perhaps the best known is that of March 26, 1812, when some 10,000 people perished in the destruction of Caracas. The great earthquake in South America on August 13, 1868, was as severely felt in Venezuela as anywhere, and the waters of some of the great rivers were for a short time so much affected as to overflow their banks. Great damage was done in the Andine towns in 1894, and in Caracas in 1900, while shocks were experienced in the former region during the author's visit in 1910; these were, however, unimportant as regards effect. Venezuela thus enjoys an unenviable notoriety as an earthquake country, but the shocks are remarkable for their linear character, both as regards the area in which they occur and in their effects, for practically no serious shocks have been experienced outside the region of the Cordilleras.

As associated phenomena may be mentioned the hot springs, also confined to the region of the Cordilleras. The most notable is that of Las Trincheras, between Valencia and Puerto Cabello, where the waters reach a temperature of about 195° F. or even 206° (Karsten, 1852); these springs rise through the schists and gneisses of the Caribbean Series, and they contain large quantities of sulphur. Throughout the Cordilleras many hot springs are known, and southward of Carupano one was found by Wall to be at boiling-point, while in the Andes the springs, though numerous, have in general a low temperature.

V. Economic Minerals.

On the side of economic geology Venezuela cannot be said to have been explored in more than a superficial way, leading in the first place to exaggerated ideas of the wealth of the country, in the second to an almost equally unfortunate lack of appreciation of the possibilities of its mineral wealth.

Coal has been worked at several points, though most extensively in the mines of Naricual, near Barcelona; the seams found appear to be Tertiary for the most part, and there are also Cretaceous coals. The Segovia Group may be the source at Naricual, as it is in Lara, but there is some doubt as to the age, and the Cerro de Oro Group is equally possible; in the Andes the latter has coals at many points, and there are lignites of high quality, as well as coals, in the Cumaná Series of the Coro and Maracaibo region. Iron ores have been found in many places and in rocks of every group, but have not been considered workable; the deposits of magnetite in the Guayana gneisses on the Rio Imataca seem to be of a size to warrant exploitation, and the ore is said to contain 65 per cent or more of metal.

Gold, as the metal which originally attracted European adventurers to explore these regions of South America, may be said to occur in almost every State of Venezuela, but generally in quantities too small to be more than a curiosity. Wherever the Caribbean Series forms the mass of the Cordilleras, occurrences of gold-bearing quartz are not uncommon, and near Carupano lodes have been found to yield 7 ounces to the ton. When Sir Robert Dudley visited the Paria coast in 1595 he heard of a gold-mine near Orocoa (Uracoa), on the eastern border of the Llanos, which may possibly have referred to gold-bearing gravel there, but the source of the commercial gold has always been the Guayana region, principally round the head-waters of the Cuyuni in the neighbourhood of Guacipati. Here auriferous gravels chiefly have been exploited, but the metal is derived from the Archæan immediately below. In British Guiana, where the conditions are similar, Mr. Harrison says that the gold is generally found along the basic intrusive dykes, and the veins are particularly rich where these traverse the older quartz-porphyries and felsites; the best are found near the smaller dykes.

Copper is widely distributed in the Northern Cordillera, and has been worked for many years at Aroa, where the veins of pyrites occur in metamorphosed limestone (? Capacho). At Seboruco in Tachira, in the neighbourhood of Balladores in Merida, and at many other points in the Andes, the Caribbean Series, or the Cretaceous rocks in association therewith, contain copper ores, some of which have been worked. Galena, both argentiferous and otherwise, also occurs in the granite region of the Andes.

Petroleum, in its varied forms, occurs at many points in Northern Venezuela, and appears to exist in greater or less quantity in all groups from the Segovia Sandstones to the Cumaná Series. The asphalt of Bermudez, from the last-named series, has become widely known, and the oil of Trujillo and Tachira, from Cerro de Oro rocks, has been exploited to some extent by local companies. Sulphur is found in considerable quantity, presumably in the Capacho Limestones, both in Eastern Venezuela and in Falcon. Mention may also be made here of the 'Urao' lake at Lagunillas, near Merida, which contains a large proportion of Sesqui—carbonate of soda, rarely found in nature; and apparently in this case derived from rocks of the Segovia Group.

VI. Bibliography.

Ahrensburg (H.). "Erdbeben in Caracas": Mitt. Geogr. Ges. Jena, Bd. xix, pp. 56–8, 1901.

Attwood (G.). "A Contribution to South American Geology": Quart. Journ. Geol. Soc., vol. xxxv, pp. 582–90, map, 1879.

Bendrat (T. A.). "Geologic and Petrographic Notes on the Region about Caicara, Venezuela": Amer. Journ. Sci., ser. iv, vol. xxxi, pp. 443–52, 1911.

Boussingault (J. B.). "Les Sources Thermales de la Chaîne du littoral du Venezuela": Compt. Rend., t. xci, pp. 836–41, 1880.

Buch (L. v.). "Von Aptychus, und über die Anden von Venezuela": Zeitschr. deutsch. geol. Ges., Bd. ii, pp. 339–44, pl. x (1850).

Cortes (E.). "Escursioni geologiche al Venezuela": Boll. Soc. Geol. Ital., vol. xx, pp. 447–69, 1901.

Drevermann (Fr.). "Ueber Untersilur in Venezuela": N. Jahrb., Bd. i, pp. 91–3, pl., 1904.

Foster (C. Le Neve). "On the Caratal Goldfield": Quart. Journ. Geol. Soc., vol. xxv, pp. 336–43, 1869.

Gerhardt (K.). "Beitrag zur Kenntniss der Kreide-formation in Venezuela und Peru": N. Jahrb., Beilage-Band xi, pp. 65–117, 1897.

Humboldt (F. H. A. v.). "Esquisse d'un Tableau Géologique de l'Amérique méridionale": Journ. Phys., t. liii, pp. 30–59, 1801.

—— "Account of the Earthquake which destroyed the town of Caraccas on March 26, 1812": Edinb. Phil. Journ., vol. i, pp. 272–80, 1819.

Karsten (H.). "Letter from Puerto Cabello on the Geology of Western Venezuela": Ber. Acad. Wiss. Berlin, 1849, pp. 197–200.

—— "On the Neocomian Rocks near Trujillo": ibid., pp. 370–6.

—— "Tertiary and Cretaceous in Cumaná and Barcelona": Zeitschr. deutsch. geol. Ges., Bd. ii, pp. 86–8, 1850.

—— "Beitrag zur Kenntniss der Gesteine des nordlichen Venezuela": ibid., pp. 345–61.

—— "Ueber die geognostische Verhältnisse des nordlichen Venezuela": Archiv Min. Geogn., Bd. xxiv, pp. 440–79, 1851.

—— "Geognostische Bemerkungen über die Umgebungen von Maracaibo und über die Nordküste von Neu Granada": ibid., Bd. xxv, pp. 567–73, 1853.

—— "Reise-notizen über die Provinz Cumaná in Venezuela": Westermann's Monatshefte, 1859.

—— "Die geognostische Beschaffenheit der Gebirge der Provinz Caracas": Zeitschr. deutsch. geol. Ges., Bd. xiv, pp. 282–7, 1862.

—— *Géologie de l'ancienne Colombia Bolivarienne.* 4to; pp. 62, map. Berlin, 1886.

LORIE (J.). "Fossile Mollusken von Curacao, Aruba und der Küste von Venezuela": Samml. Geol. Reichs-Mus. Leyden, ser. II, Bd. i, pp. 111–49, 1887.
SALOMON (W.). "Ueber angeblichen Untersilur in Venezuela": Monatsb. deutsch. geol. Ges., 1909, p. 193 (shows that specimens described by Drevermann were bought in U.S.A. and were not from Venezuela).
SIEVERS (W.). "Das Erdbeben vom 26 Marz, 1812, an den Nordküste Sudamerikas": Mitt. Geogr. Ges. Hamburg, 1884, pp. 265–71.
—— "Reiseberichte aus Venezuela": ibid., pp. 272–87; 1885–6, pp. 1–133.
—— *Venezuela.* pp. viii, 359. Hamburg, 1888.
—— "Karten zur physikalischen Geographie von Venezuela": Petermann's Mitt., Bd. xlii, pp. 149–55, 197–201, 3 maps (1 : 3,000,000), 1896.
—— "Das Erdbeben in Venezuela vom 29 Okt., 1900": Jahrb. Veröffnet. Geogr. Ver. Bonn, 1905, pp. 35–50.
STEVENS (R. P.). "Geology and Mineralogy of Venezuela": Proc. Acad. Nat. Sci. Philadelphia, 1868, pp. 303, 304.
TATE (R.). "Notes on the Geology of Guyana in Venezuela": Quart. Journ. Geol. Soc., vol. xxv, pp. 343–50, 1869.
WALL (G. P.). "On the Geology of a part of Venezuela and Trinidad": Quart. Journ. Geol. Soc., vol. xvi, pp. 460–70, 1860.

IV.—THE CLASSIFICATION OF THE ROCKS OF THE WESTERN AUSTRALIAN GOLDFIELDS.

By J. ALLAN THOMSON, B.A., B.Sc., F.G.S.

(*Concluded from the April Number, p. 153.*)

Sedimentary Formations in the Goldfields.—Sedimentary rocks are rare in all the goldfields south of the Gascoyne River, if superficial deposits of Tertiary or Recent age be omitted. It is true that a sedimentary origin has at times been ascribed to the jaspers, and still more commonly to the bands of graphitic schists within the greenstones. Hand-specimens of the latter rocks and of slaty rocks associated with the jaspers are indistinguishable from similar rocks of sedimentary origin, and it is only by the study of the geological occurrence of the bands that their derivation from igneous rocks can be proved. It is probable, therefore, that many of the rocks mapped as 'older sediments' by W. D. Campbell in Kalgoorlie[1] and Norseman[2] are not sediments. There are, however, undoubted sedimentary rocks between Kalgoorlie and Coolgardie, viz. the Kurrawang conglomerates. The enclosed pebbles are largely jaspers and porphyries, so that the formation of the conglomerates must be posterior to the intrusion of the granites, and yet the matrix is sub-schistose and the axes of folding are parallel to the general direction of foliation of the district. The junction with the auriferous series cannot be seen. From the photo reproduced by Campbell, it appears that there are similar conglomerates at Norseman.[3]

It is in the north-western goldfields the sedimentary series are best developed and best exposed. Probably the oldest is a series of highly inclined quartzites, conglomerates, quartz-schists, mica-schists, etc., which is associated at Warrawoona with the basic

[1] *Geological Map of the Kalgoorlie Goldfield*, A. G. Maitland and W. D. Campbell, Perth, 1902.
[2] Bull. xxi, pp. 33–5, 1906. [3] Loc. cit., fig. 10.

schistose rocks of the auriferous series.[1] The relationship of the two series has not been worked out, but from a consideration of the map it appears probable that the basic schists are either contemporaneous volcanic rocks or later intrusions. The relationship could be most easily solved by examining the sedimentary series for traces of contact action, and determining the nature of the pebbles in the conglomerates.

Another highly folded but probably later formation occurs in the Nullagine District, Pilbara Goldfield, and has been termed the *Mosquito* Creek Series by Maitland.[2] The rocks consist of grits, sandstones, shales, and fine conglomerates, all considerably sheared. Nevertheless, the series must be younger than the auriferous series, for the conglomerates contain numerous pebbles of the laminated jaspers of the latter, in this resembling the Kurrawang conglomerates between Kalgoorlie and Coolgardie. An observation of great interest is that the Mosquito Creek Series is intruded by a granite and forms the matrix of numerous auriferous quartz reefs.

In the West Pilbara, Ashburton, and Gascoyne Goldfields highly inclined and sub-schistose sedimentary rocks are met with at Bangemall, Uaroo, Westons, and Roeburne.[3] Besides quartz-schists, arkose, conglomerate, and phyllites, they include a large number of beds of limestones, dolomites, and cherts. At Roeburne they are intruded by dykes of amphibolites after gabbros and gabbro-pegmatites in every way comparable to rocks of the auriferous series, and probably belong, therefore, to the Warrawoona Series. At Mt. Phillips, near Bangemall, they rest unconformably upon a granite. All these rocks form the matrices of gold and copper lodes.

These highly folded beds are covered unconformably in the Pilbara Goldfield by rocks of plateau type to which the name of the *Nullagine* Series has been given.[4] Though thrown into a series of gently undulating folds the series is on the whole approximately horizontal. Besides sedimentary members such as sandstones, grits, conglomerates, and limestones, there is a well-defined volcanic series of lavas, ashes, and conglomerates. The age of these beds has been variously ascribed to Cambrian and Devonian, from lithological resemblances to fossiliferous beds of those ages in the Kimberley District. The probabilities are in favour of a Devonian age, for the known Devonian has also a volcanic series well developed.

The basal conglomerates of the Nullagine Series consist chiefly of fragments of pre-existing conglomerates, cherts, grits, and shales of the Mosquito Creek Beds, and of reef quartz, identical in character with that forming the auriferous deposits of the underlying strata.[5] They appear thus to be posterior to the main deposition of gold, but the conglomerates are themselves in places auriferous, although whether the gold is authigenous or allothigenous is a matter of uncertainty.

[1] A. Gibb Maitland, Bull. xx, pp. 57–61, 1905; Bull. xxiii, pp. 77, 79, 1906.

[2] Bull. xx, pp. 28–30, 1905; Bull. xxiii, pp. 77–9, 1906.

[3] Maitland, Bull. xxxiii, pp. 42–5, 66–7, 75–6, 99–100, 1909.

[4] Maitland, Bull. xv, pp. 10, 11, 25, etc., 1904; Bull. xx, pp. 23–8, 1905; Bull. xxiii, pp. 40–3, 77–8, 1906; Bull. xxvi, pp. 50–2, 1907.

[5] Bull. xx, pp. 24–5, 1905.

Basic Dykes.—Dykes of basic rocks are of frequent occurrence, not only in the rocks of the auriferous series, but also in the gneisses, the granites, and the older sedimentary rocks. Some of them penetrate various members of the Nullagine Series, and may be the feeders of the volcanoes of that period. The only later period of vulcanicity known in the State belongs to the Tertiary, but the rocks are confined to the Kimberley District, and very little is known about them. It is possible that the rocks under discussion belong to more than one period. All that can be said of most of them is that they are later than the folding or foliation of the granites and the deposition of the gold, and anterior to certain faults.

IV. Results of the Writer's Petrographical Studies.

The writer's acquaintance with the rocks of Western Australia commenced in London in 1908 with the preparation of a petrographical report to accompany Bulletin 33 of the Geological Survey. Some seventy rocks were examined and described in detail, but the value of the report was lessened by the writer's ignorance of the general features of Western Australian geology, and of the particular occurrence of the rocks in hand. Subsequently a year was spent (1909–10) as assistant to Dr. J. M. Maclaren in a private geological survey of Kalgoorlie, the results of which are not yet published. Some hundreds of slides of rocks from Kalgoorlie, Coolgardie, Kanaona, Leonora, and Day Dawn were carefully examined. Before leaving the State, the writer took the opportunity to look through the large series of rocks collected by the Geological Survey, and the Director, Mr. A. Gibb Maitland, kindly placed at his disposal duplicate specimens of some two hundred selected rocks, many of which had been analysed. Visits to Southern Cross and Albany made up the writer's collection to over three hundred rocks. Sections of these have been prepared and briefly examined with a view to the preparation of this paper. Finally, in Sydney the writer was able to examine, through the kindness of Professor David, a series of sixteen rocks collected by the David Lindsay Expedition to Central Australia. A paper embodying the results of this examination has been submitted to the Royal Society of New South Wales.

The majority of the rocks examined belong to the auriferous series. A large number of them are coarse-grained massive amphibolites which bear abundant internal evidence of their derivation from basic intrusive rocks such as pyroxenites, hornblende dolerites, olivine dolerites, dolerites, and quartz dolerites. The same rock species are also represented by massive chloritic greenstones and by fissile chlorite schists. Ultrabasic intrusions are represented by serpentines, talc-carbonate schists, and magnesite rocks. All these rocks appear to be intrusive into fine-grained amphibolites and chloritic greenstones that contain little internal evidence of their original structure, but must be regarded as forming a volcanic series. A distinction may thus be made between older and younger amphibolites and greenstones. Within the contact aureoles of the granites these distinctions are not so easy, for all the rocks have been transformed into hornblende and talc-tremolite schists retaining no evidence of their internal structure, except, perhaps, the coarse or fine texture. There are only a few garnetiferous amphibolites in the Phillips River Goldfield for which a possible sedimentary origin can be admitted. An examination of the jaspers in the contact-altered schists proves that they too are contact-altered, and are therefore anterior in formation to the intrusion of the granite.

The granites and porphyries have not as yet been examined in great detail, but it appears possible to group the former into biotite-microcline granites, hornblende-granites or tonalites, and albite-granites. Each of these has its characteristic dyke accompaniment. Many of the basic dykes consist of very fresh dolerites and quartz-dolerites, and show so many points of similarity to the Karroo dolerites of South Africa and the Mesozoic dolerites of Tasmania, that it is not improbable that they are all of the same age. This view has been elaborated in the paper read before the Royal Society of New South Wales referred to above. Others are in a state of alteration intermediate between these and the amphibolites of the auriferous series.

The Nullagine volcanic rocks are entirely different in their state of alteration from the rocks of the auriferous series. They are, as far as examined, practically structureless aggregates of chlorite, epidote calcite, and quartz. Some of the rocks intrusive into the Devonian of Kimberley, however, appear to present a greater degree of constructive metamorphism. One of them is an epidosite containing an amphibole related to glaucophane.

V. Principles of Classification.

The requisites for an entirely satisfactory classification of a rock are a knowledge of—

1. Its mode of origin, whether sedimentary, volcanic, or intrusive.
2. Its age.
3. Its original lithological character.
4. Its state of alteration.

If the age is known, the rest is largely a matter of petrographical and chemical study. As far as possible the evidence for the age of each of the main groups has been discussed above, but the principles involved will be brought together here for greater clearness. It is not necessary to discuss the ordinary principles of stratigraphy by which the aid of sedimentary rocks is determined. The age of a given intrusive rock is fixed within certain limits—

1. If it can be shown to be intrusive into any rock of known age. Too great importance cannot be laid on the necessity of obtaining evidence of contact-alteration in the surrounding rocks when the intrusive nature of any rock is in doubt.

2. If it is in turn traversed by intrusive rocks of known age.

3. If it is covered unconformably by a sedimentary rock of known age. To be entirely satisfactory this evidence should be supplemented by an absence of contact-metamorphism in the overlying rocks, and by the presence of pebbles of the intrusive rock in the conglomerates of the younger series.

4. If it can be shown that its date of intrusion was before, within,

or after the period of foliation of the rocks into which it is intrusive. To attach an age significance to this relationship, it is necessary to assume that the foliation is of the same general age over the whole State. This is a perfectly justifiable assumption in the present state of our knowledge. Traces of a double foliation have been observed in gneiss at Big Sherlock River, Pilbara Goldfields, by Cadell:[1] "The older and coarser banding has a north and south strike at Big Sherlock Station, and at right angles to this there are zones of secondary and much finer foliation, within which it has the character of a mylonite," etc. With this exception there is no evidence as yet brought forward to show two distinct periods and directions of foliation such as exist in the Lewisian and Dalradian of Scotland. Variations in strike between different districts amount to nearly 90°, but whether this is due to different systems or to curving trend-lines is uncertain. A map of the State showing the trend-lines would be a great boon. For the present we may regard the foliation as of one age.

5. If it can be shown that its date of intrusion is anterior or posterior to the formation of auriferous quartz-reefs. Several distinct modes of gold occurrence exist in the State, and these may not necessarily be of the same age. Nevertheless, the presumption is, as suggested by W. Lindgren,[2] that the *mise-en-place* of the gold closely followed the intrusion of the granites, and belongs to one period.

6. If it can be shown that its intrusion is anterior or posterior to faults of known age. Little is yet known as to the age of the various systems of faults, but this line of evidence may yet yield important results.

VI. Suggested Classifications.

From the application of the above-mentioned considerations, the classification outlined below is suggested. It is put forward as a working hypothesis and will serve a useful purpose if it directs attention to the gaps in our knowledge. The rocks are arranged in ascending order of age.

I. Pre-Nullagine	A. Pre-foliation	1.		Fundamental gneisses and schists.
		2.	*a.*	Warrawoona sedimentary series.
			b.	Older amphibolites (volcanic).
		3.	*a.*	Later amphibolites (intrusive).
			b.	Older granites and porphyries.
		4.		Jaspers.
		5.		Mosquito Creek Series.
	B. Post-foliation	6.		Newer granites and porphyries.
		7.		Gold deposits.
		8.		Post-gold acid intrusions.
II. Nullagine Series		9.	*a.*	Nullagine sediments.
			b.	Nullagine volcanics and their feeding pipes.
III. Post-Nullagine		10.		Basic dykes.

The principal gaps in our knowledge relate to the granites, porphyries, and basic dykes. These may be of many ages. Some

[1] Trans. Edin. Geol. Soc., vol. vii, p. 181.
[2] *Econ. Geol.*, vol. i, p. 530, 1906.

of the basic dykes are only known to be post-granitic, some to be post-gold, while a few are post-Nullagine. A comparison of their petrographical character and state of alteration may show whether more than one series is present, while their direction of alignment may also help to differentiate two or more series. Only one granite is definitely known to be post-Mosquito Creek, but as this sedimentary series contains gold reefs, it is probable that all the granites that can be distinctly correlated with the deposition of gold belong here. Many of the granites are rather inter-foliation than post-foliation, for they are gneissose along their margins, and the accompanying dykes are considerably sheared.

VII. Detailed Petrographical Studies.

The writer proposes to give the results of his detailed studies on the rocks of the auriferous series, the jaspers, the granites, and the basic dykes in subsequent papers. As a contribution to the knowledge of the fundamental gneisses the following is offered. Little is known of the geological occurrence of these rocks, but their structures favour the view that they are highly metamorphic.

G.S.M. 832. (This and subsequent numbers refer to the Register of the Geological Survey Museum, Perth.) This is a well-foliated biotite-microcline gneiss from Loc. 1046, N.W. of Mt. Dick, Mortlock River, Northam, i.e. in the western granite belt of Woodward. The darker layers owe their colour to small plates of biotite aggregated more or less in bands, and lying with their cleavage planes in the planes of foliation. In the lighter-coloured layers quartz and felspars predominate. A plagioclase (oligoclase-andesine) occurs sparingly in large elongated and much striated crystals with its longer axes in the planes of foliation. Quartz also occurs in elongated and similarly oriented crystals, separated by numerous small rectangular plates of microcline. An interesting feature in the slide studied is a graphic intergrowth of two adjacent crystals of quartz. Iron-ores are practically absent and accessories rare. The rock has the composition of a microcline granite and the structure of a gneiss.

G.S.M. 2286[1] is a hornblende-biotite gneiss from Dalgety Creek, Lyons District, east of Gascoyne. It is not so perfectly foliated as the preceding rock, for the biotite plates follow the boundaries of large rounded slightly sericitic oligoclase crystals. Both the felspar and the biotite exhibit bent cleavage-planes and twin-planes and undulose extinctions. The biotite is frequently crowded with rutile, sometimes in small stout prisms, at other times in hair-like sagenitic needles. Quartz is fairly abundant in small clear anhedral plates between the felspars. There are no minerals with refringence less than that of balsam, so that potash felspars are absent. A green hornblende, subordinate in amount to the biotite, occurs in small euhedral prisms. Apatite is the only accessory.

G.S.M. 8692, from Goddard's Creek,[2] in the south-eastern corner of

[1] Some confusion exists as to whether the section described really belongs to 2286, owing to a mistake in labelling by the lapidary.
[2] Cf. Bull. xxxvii, pp. 14–15, 1909.

the State, is not a well-foliated rock, but has both the mineral composition and the structure of a typical crystalline schist. The minerals noted are garnet, biotite, sphene, apatite, a plagioclase near andesine, orthoclase, and quartz. The garnet is not distinctly euhedral, and is full of inclusions of the other minerals. Sphene occurs in small characteristic acute prisms. The chief structural peculiarities are the frequent inclusion of quartz in rounded plates within the orthoclase, and the presence of intergrowths of quartz and plagioclase (Fig. 1).

These intergrowths have the gridiron shapes characteristic of 'myrmekite', rather than the script-like forms that have given rise

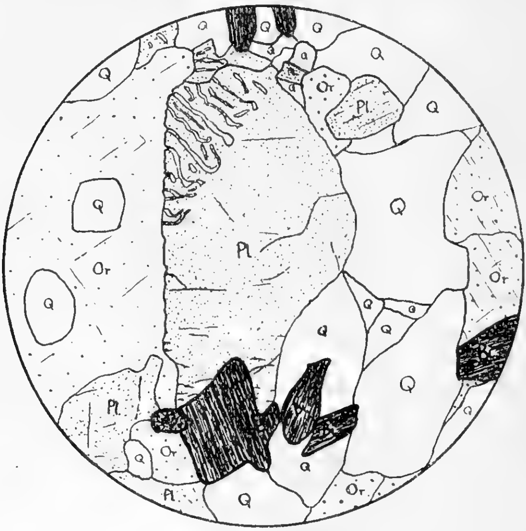


FIG. 1. Gneiss showing the inclusion of quartz in orthoclase and a myrmekitic intergrowth of quartz and andesine. Magnification, 42 diameters. Ap. = apatite ; Bi. = biotite ; Pl. = plagioclase ; Or. = orthoclase ; Q. = quartz.

to the term 'graphic'. They are strictly confined to the plagioclase. Myrmekite in Sweden is considered a sign of extreme metamorphism and great age in granite.[1]

Two rocks collected by the writer on the beach between Albany and the Pier resemble the last-described rock in both these structural features, viz. the inclusion of quartz in orthoclase and the myrmekitic intergrowth of quartz and a plagioclase near oligoclase in composition. They are hornblende-biotite gneisses, with hornblende in equal or greater amount than biotite. A further structural peculiarity is the occasional presence of myrmekitic intergrowths of quartz and biotite (Fig. 2) and quartz and hornblende.

[1] J. P. Holmquist, "Studien über die Granite von Schweden": Bull. Geol. Inst. Upsala, vol. vii, p. 116, 1904–5.

Orthite occurs in the centres of fairly large prisms of epidote, and has determined pleochroic haloes in the biotite. Zircon and apatite are abundant in minute prisms. Of these rocks, the one is well foliated, the other massive, and mineralogically they differ chiefly in the larger amount of hornblende compared to biotite in the latter. The massive rock might easily be taken in the hand-specimen for an ordinary granite, but from its structural peculiarities must be assigned to the gneiss complex, which at Albany is intruded by a coarsely porphyritic pink granite of probably much later age. Among the gneisses garnetiferous varieties were seen, but have not been studied in thin section.

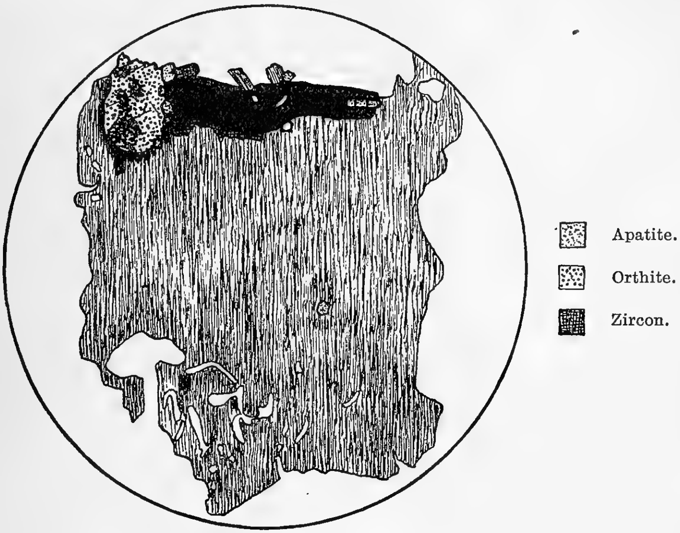


FIG. 2. Detail from gneiss showing biotite myrmekitically intergrown with quartz in the bottom left-hand corner and associated with and partially enclosing orthite, apatite, magnetite, and zircon. Magnification, 34 diam.

The writer's thanks are due to Messrs. A. Gibb Maitland, Harry P. Woodward, and C. G. Gibson for unfailing kindness during his residence in Western Australia, and for much verbal information which has enabled him to form clear views on the geology of districts which he has not been able to visit. To Dr. J. M. Maclaren, also, he is indebted in a manner difficult to estimate, since most of the above ideas were freely discussed with him during a year's close association. None of these gentlemen, however, can be committed to the classification outlined above.

V.—Some Handiworks of Early Men of various ages.

By the Rev. O. Fisher, M.A., F.G.S.

(WITH FOUR TEXT-FIGURES.)

In the following notes I propose to chronicle a few works of early man other than chipped flints in this country, which during a long life have come under my own observation. They shall be arranged in order of antiquity, and, as might be expected, the earliest will be the most doubtful. Nevertheless, in anticipation of its being possibly confirmed by future discoveries it shall not be passed over.

1. When digging for fossils in the Eocene of Barton Cliff I found a piece of a jet-like substance about 9½ inches square and 2¼ inches thick. There was a large oyster-shell attached to the upper surface. It bore on at least one of its sides what seemed to me to be marks of the chopping which had formed it into its accurately square shape. This specimen is now in the Sedgwick Museum, Cambridge.

2. The next in antiquity was the cut bone from the Crag, which I first saw in the collection of Mr. Whincopp, of Woodbridge, and which he called a bludgeon. It afterwards passed into the hands of Sir Joseph Prestwich, and is now in the British Museum. It was described by me and is figured in this Magazine[1] (Fig. 1).

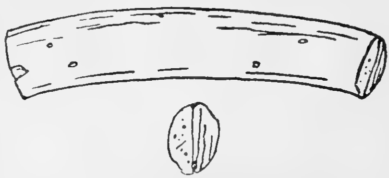


Fig. 1. Piece of a fossil rib, partially sawn across at both ends. From the Red Crag. Part of the late Mr. Whincopp's collection. Scale 2 inches to a foot.

The suggestion that man could have existed in Pliocene times was of course received with due scepticism; but the recent discovery of worked flints from the Crag[2] is in remarkable accordance with the supposition that the thing was the weapon of a human being of that period. The two finds confirm one another.

3. The next in order of time is a work of a different character. I refer to the elephant trench at Dewlish in Dorsetshire. This trench was excavated in chalk and was 12 feet deep, and of such a width that a man could just pass along it. It is not on the line of any natural fracture, and the beds of flint on each side correspond. The bottom was of undisturbed chalk, and one end, like the sides, was vertical. At the other end it opened diagonally on to the steep side of a valley. It has yielded abundant remains of *Elephas meridionalis*, but no other fossils. I have described it with two photographic views in the Journal of the Geological Society,[3] and it may be noticed that in one narrow place the sides mutually approach one another, a feature

[1] 1905, p. 575. [2] Moir, Proc. Prehistoric Soc. of East Anglia, 1911.
[3] Q.J.G.S., vol. lxi, pp. 35–7, 1905.

which can hardly be explained by any natural process. This trench, in my opinion, was excavated by man in the later Pliocene age as a pitfall to catch elephants; and, if so, it proves that he was already an intelligent and social being, because no single hand could have accomplished so great a work.

4. Excepting stone the most enduring substance employed by primeval man was bone, and the instance of the use of this material that first came under my observation was the cut rib bone, supposed of an elephant, found by Blake in the gravel of Barnwell near Cambridge, and described by the late Professor H. G. Seeley.[1] This bone was not sawn, but notched round and then broken. The gravel at this locality contains *Elephas antiquus* and the southern shell *Cyrena fluminalis*.

FIG. 2. Base of shed antler of red deer (*Cervus elaphus*) from Barrington. Circumference above burr, 9 inches. Antlers partly sawn and then broken off.

5. The terrace of gravel at Barrington,[2] which is about seven miles from Barnwell higher up the drainage system, has been extensively excavated, and has yielded many well-preserved mammalian remains, of which a large number are in the Sedgwick Museum at Cambridge. The species of elephant is *E. antiquus*, but *Cyrena fluminalis* does not occur. Several bases of deer's antlers have been found here, from which the branches and tines have been sawn off. One of these in the collection of the Rev. E. Conybeare is now figured (Fig. 2). This was a shed horn, but some of the bases have portions of the skull attached, which shows that the animals had probably been killed. In the *Geologist* for 1861 [3] I have described and figured such a specimen, which evidently had been chopped off the skull, the marks of chopping

[1] Q.J.G.S., vol. xxii, p. 470.
[2] See Professor Hughes, Proc. Geol. Assoc., vol. xxii, pt. v, **1911**.
[3] *Geologist*, vol. iv, pp. 352–4, pl. ix, 1861.

being distinct. It was dredged up at a spot called the Wallet, off Clacton, in dredging for cement stone, and was in the possession of Dr. Bree, of Colchester. *Cyrena fluminalis* occurs in the Pleistocene cliff at Clacton, which seems to correlate the deposit with the Barnwell gravel.

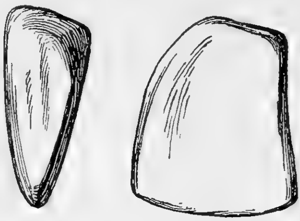


FIG. 3. Piece of red ochre cut into shape for marking lines, from Grantchester. Length, 1 inch; width, $\frac{3}{4}$ inch; $\frac{3}{8}$ inch in thickness at butt end.

Probably in these cases the antlers were cut off for use, and the bases thrown away. I have not seen any fossil antler. We know that the antlers of red deer were used as picks by Neolithic man, because they have been found in the flint-mines at Grime's Graves near Brandon. What saw did these ancient people possess? That it was not very efficient is shown by the marks it has left, and they seem to have saved themselves the trouble of sawing as soon as the object could be broken.

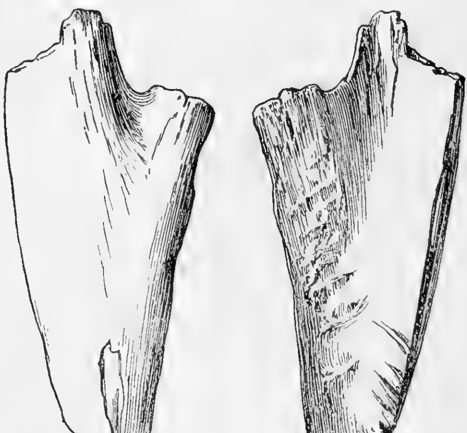


FIG. 4. Cut fragment of bone from Bedfordshire. Reduced to two-thirds natural size.

6. At one time, when I was digging for bones in the gravel at Barrington,[1] I found two round stones of the same size near one another. One of them was a flint nodule, the other of a different rock. They attracted my attention at the moment, but their possible

[1] Q.J.G.S., vol. xxxv, pp. 670–7, 1879.

significance did not occur to me then, and I did not preserve them. I afterwards thought that they might have been bolas, such as are used in South America for catching game. They were of a suitable size for such a purpose.

7. During the time when the Upper Greensand of Cambridgeshire was being extensively worked for phosphatic nodules (miscalled 'coprolites'), a pit was opened in 1880 near Grantchester vicarage house.[1] The heading consisted of a bed of gravel containing teeth of *Elephas primigenius* and among others many shells of *Cyrena fluminalis*.

At a depth of 12 feet in this gravel was found a piece of red ochre, cut into a form somewhat similar to that into which tailors cut french chalk for marking cloth, a form especially suitable for drawing lines. Its specific gravity is about 4·5. It is now figured

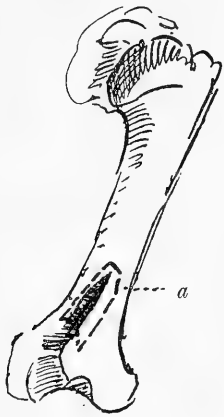


FIG. 5. Rough sketch to show "Lower end, posterior part of left humerus of a large ungulate, probably *Bos taurus*, showing the part (*a*) from which the above fragment (see Fig. 4) was obtained; the hollow is part of the natural configuration of the bone" [W. L. H. D.].

(Fig. 3). It is an inch long, three-quarters of an inch wide at the edge, and three-eighths thick at the back. I sent this specimen to Professor Boyd Dawkins for his opinion, and he replied that a bit of 'raddle' had been found in the Creswell Caves, and that "he had no doubt that the palæoliths raddled themselves". Frequent mention of the use of this material will be found in that instructive work, Sollas' *Ancient Hunters*. An interesting point about this find is that it indicates traffic at that early period between distant places, because this mineral does not occur anywhere near, but must have been brought from a great distance. At present it is mostly obtained from the Mendip Hills in Somersetshire.

8. On a heap of gravel brought to repair the line at Lord's Bridge Station on the Cambridge and Bedford Railway, I found the piece of

[1] See an exhaustive paper on the Pleistocene Mollusca of the neighbourhood of Cambridge, by Mrs. McKenny Hughes, this Mag., 1888, p. 191.

bone now figured (Fig. 4). It is of a brown colour and much mineralized. I was told that the gravel came from Bedfordshire, possibly from the Biddenham pits, where Mr. Wyatt obtained many flint implements. It shows at one end cut marks on both surfaces. Dr. Duckworth informs me that it is from the lower end of the posterior part of the left humerus of a large ungulate, probably *Bos taurus*, and he has pointed out the position of the fragment (Fig. 5), showing that the hollow, which so conveniently fits the fore-finger and causes the thing to lend itself so readily to the hand, as Sir Joseph Prestwich remarked to me, is a part of the natural configuration of the bone. It does not seem probable that a fragment of that shape should splinter off such a bone unless it was broken intentionally. The article seems just suitable to be used spoon-fashion, and it would serve well for scraping the marrow out of a split bone. If that was its purpose, I think it is a rare instance of finding a Palæolithic implement intended for personal convenience.

VI.—The Plates of the Buccal Membrane in *Echinocorys.*

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

A SPECIMEN of *Echinocorys* showing the plates of the peristome was exhibited at the Conversazione of the Geologists' Association in 1910 by Mr. W. H. Bennett, and has, through the courtesy of that gentleman, been forwarded to me for detailed examination. In view of the perfect preservation of the peristomial structures, and the extreme rarity of their discovery, I have thought it advisable to publish the following short description. A comparison is made between the structure shown in this specimen and that described by Lovén in the young stages of *Echinocardium.*

Description of the Test. The broken test, of which only the anterior part of the base is preserved, was found by Mr. Bennett on beach reefs 100 yards east of the steps at 'Black Rock', Brighton, in the upper part of the zone of *Marsupites.* The form would seem, judging by the fragment remaining, to have been a characteristic example of the variety of *Echinocorys vulgaris* called *pyramidatus* by English workers, this variety being almost restricted to the *Marsupite*-zone. The base is almost flat, and the sides are curved up from it through rather more than a right angle, making the edge of the adoral surface coincident with the greatest width of the test.

The flatness of the base is interrupted around the peristome, which is situated in a considerable hollow. The portion of the test between the anterior margin and the peristome is inclined sharply towards the interior of the Echinoid, and on the other side of the peristome the plastron rapidly regains the ambital level. Part of the concavity thus formed contains the large podial pores and their attendant tubercles, the deepest part alone being occupied by the peristome.

The Shape of the Peristome. The peristome is a roughly elliptical aperture, whose greatest width (transverse measurement) is 6·1 mm. This diameter is towards the posterior part of the opening. The greatest length (antero-posterior measurement) is 4·4 mm., this being absolutely on the long axis of the test. The area of the peristome is not flat, and hardly in any part parallel with the adoral surface of the test. The most deeply sunken part is at the anterior margin, and, with the rest of the test, the edge of the peristome curves sharply up towards the plastron from about the region of its greatest width. This feature is indicated in Fig. 1, B. The actual margin of the peristome is visible in the specimen under description only in its posterior part, being overlapped anteriorly by the peristomial plates. This is probably due to the warping of the membrane on which these plates were fixed. In ordinary specimens, however, the margin is completely smooth, without any trace of sockets for the articulation of the peristomial plates.

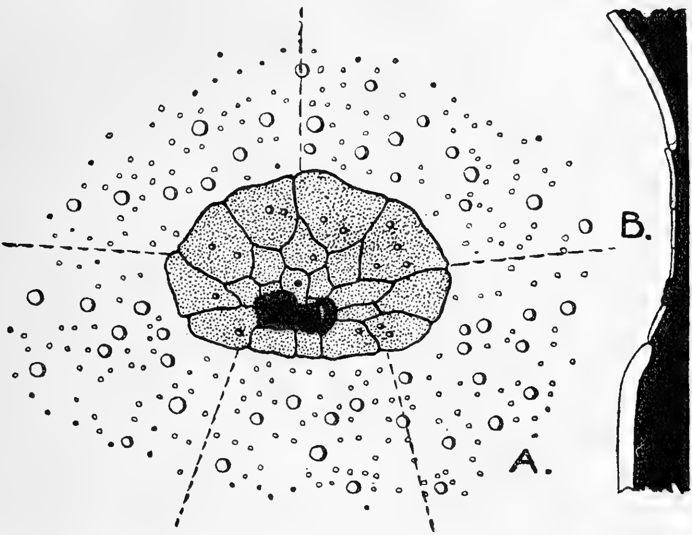


FIG. 1. Plating of the buccal membrane in *Echinocorys*. A, camera lucida drawing, × about 6·5 ; B, sectional view, diagrammatic.

The Peristomial Plates. The plates of the peristomial membrane are preserved in situ, the slight displacements that they show being probably due to the inward contraction of the membrane after death. They are polygonal, mostly pentagonal, in shape, and seem to be exceedingly thin. The surface of all of them is finely shagreened, in contrast to that of the coronal plates, which are almost smooth between the miliaries.

The outer ring in contact with the margin of the peristome consists of eleven plates of considerable size and very regularly disposed. The sutures between them are approximately continuous with the perradial and interradial sutures of the test. The four largest plates of this cycle are towards the anterior edge, and correspond in position to the anterior radius and the two antero-lateral interradii. They are pentagonal, and, while opposing straight edges to one another, have a slightly sinuous outline externally. This probably means that they were not actually articulated to the peristome margin, which, in fact, they overlap. Posterior to these four large plates are a pair (on each side) of transversely elongated plates, very obscurely pentagonal, which correspond to the antero-lateral and postero-lateral radii and the included postero-lateral interradii. Three more or less quadrangular plates of about the same size as the last (they are foreshortened in Fig. 1, A) complete the cycle in its posterior portion. The smallest of the three is on the antero-posterior axis, so that the outer cycle is approximately bilaterally symmetrical. Many of the plates support one or more miliary granules.

The second cycle is incomplete, as far as the evidence of the specimen shows. It is composed of six elongately hexagonal plates, alternating in position with those of the outer ring. Only the anterior (radially situated) member of this series supports a granule.

The third cycle is very incomplete, consisting of three plates (with traces of a fourth) of somewhat irregular shape. The central plate has a deep hollow on it, which is probably a pore, but, as the specimen is preserved, bears considerable resemblance to a spheridial pit.

Owing to the restriction of the two interior cycles of plates to the anterior part of the peristome, the actual mouth opening is driven to the posterior half of the membrane. The smaller plates are to some degree collected round the position of the mouth in a slightly elevated cone. The mouth is situated at the foot of the sharp outward curve of the posterior part of the peristome, but is not in the deepest part of the concavity.

Comparison with peristomial plates in Echinocardium. The primitive position among the Spatangoida occupied by the Echinocorythidæ is well illustrated by a comparison of the plating of the buccal membrane in the specimen described with that of *Echinocardium.* A characteristic feature in the evolution of the Spatangidæ is the gradual increase in prominence of the labrum, and the consequent restriction of the peristomial opening to a crescent shape, when viewed from below. The zonal sequence of the *Micrasters*, as described by Rowe, illustrates this tendency very clearly.

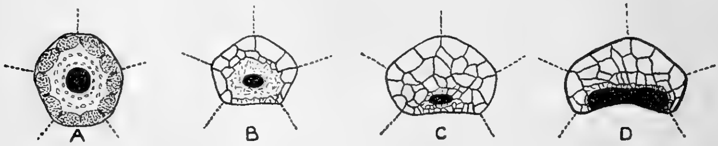


FIG. 2. Stages in development of buccal membrane in *Echinocardium flavescens.* A, in a very young specimen; D, in an adult. Modified from Lovén, *On 'Pourtalesia'* and *Etudes sur les Echinoïdées.*

Lovén has shown that in the ontogeny of *Echinocardium flavescens*, the peristome is central in the early stages, and retains its position (relative to the anterior margin) throughout growth, its later eccentricity being due to the disproportionate increase of the posterior part of the test. In two of his works (*On 'Pourtalesia'* and *Études sur les Échinoïdées*) he gives beautiful figures of the buccal plating in that species at various stages of its development. They are copied (somewhat diagrammatically) in Fig. 2 for purposes of comparison.

In the earliest stage (Fig. 2, A) the buccal membrane of *Echinocardium* is roughly decagonal in outline, and supports three cycles of plates. The inner cycles are rather irregular, but the outermost cycle is composed of ten large reticulate plates (apparently in a continuous ring) corresponding in position with the ends of the ten ambulacral columns. In all probability these buccal plates actually represent the primitive terminals of the radial plates, as in a young Diademoid. Their correspondence in position with the 'buccal plates' of *Conulus* is noteworthy, but the massive character of the latter ossicles renders their correlation with those of Spatangoids very doubtful.

In the next stage figured by Lovén, the peristome of *Echinocardium* is seen to be truncated posteriorly by the incipient labrum (Fig. 2, B). This change in shape has disorganized the plating of the buccal membrane, but only to a slight degree in the anterior region, where, for the most part, two large plates of the outer cycle intervene between each radius. The posterior part of the cycle is built of small, irregular plates. In the third stage (Fig. 2, C) the labrum has progressed to such an extent that the mouth opens very near to the posterior margin of the peristome, from which it is separated by a few minute and irregular plates. The disarrangement and multiplication (or perhaps subdivision) of the anterior and lateral plates of the outer cycle is not seriously increased from the degree attained in the second stage.

In the adult Spatangid (Fig. 2, D) the labrum has so far extended forwards that the mouth (now much enlarged) opens directly against the posterior edge of the peristome, and the only remaining buccal plates are anteriorly and laterally situated. The chief modification that has affected these residual plates is that they have become subdivided, so that three new plates represent two original ones in the two anterior sections. In the postero-lateral interradii, the lateral members of the cycle are still in the original dual grouping.

The buccal characters, both in peristome-shape and plating, in *Echinocorys* correspond to a stage intermediate between the first and second in *Echinocardium*. The primitive three cycles are quite clearly, and solely, represented in *Echinocorys*, but the ingress of the posterior margin of the peristome, while destroying the inner cycles of plates in that region, has caused a subdivision of the two posterior plates of the outer cycle into three.

Since the specimen described above is the only one in which the buccal membrane plates of a Cretaceous Spatangoid are known (so far as I am aware), it is interesting to find that the palæontological evidence is in such direct accord with that derived from ontogeny. It is probable that species corresponding to the later, and perhaps the earlier stages in *Echinocardium*, will be found among Cretaceous and early Tertiary Spatangoids.

REVIEWS.

I.—Observations on the West of England Mining Region. By J. H. Collins, F.G.S. 8vo; pp. xxi, 683, with 18 plates. Plymouth: William Brendon and Son, Ltd. 1912.

THIS substantial book, issued as volume xiv of the Transactions of the Royal Geological Society of Cornwall, embodies the results of the author's long-continued personal observations and researches on the mineral deposits and mining geology of Cornwall and parts of Devon and West Somerset. Remarkable as it seems, the author affirms that the germs of most of the generally accepted conclusions on the origin and development of the ore-deposits were put forth by geological writers in the eighteenth century. These were amplified later on and established by Carne, R. Were Fox, De la Beche, Henwood, and others, while the details of Nature's methods have been dealt with by more recent writers. The 6 inch Geological Survey of Cornwall, commenced in 1897 by Mr. Ussher in East Cornwall and by Mr. J. B. Hill in West Cornwall, has been completed so far as the mining areas are concerned, and all known particulars relating to active and abandoned mines, with sections and plans, have been published. The work, indeed, has been carried as far as Tavistock in Devon.[1] Referring to this undertaking the author observes that "The recent re-survey of our area, besides clearing up many stratigraphical problems, has thrown much light on its petrography", but he, rather humorously, adds "That as regards our ore deposits it has propounded more problems than it has solved".

It is admitted that the oldest rocks determined by fossil evidence are Ordovician, and that there is little doubt that there are earlier rocks at Start Point, the Lizard, and elsewhere in West Cornwall, rocks which are not metalliferous to any important extent. In 1881 the author first called attention to the possible Cambrian age of the rocks on the western borders of the Falmouth estuary at Ponsanooth[2] (siliceous slaty rocks since grouped by Mr. Hill with the Mylor Series), but in the present work the author does not particularly refer to them, nor does he mention the Silurian rocks discovered by Mr. Upfield Green and Mr. C. D. Sherborn at Porthluney and Porthalla.[3] The fossiliferous Ordovician rocks of Perhaver, Gorran Haven, are regarded by Mr. Philip Lake as 'apparently Llandeilo'.[4] These conclusions are important as the field-evidence obtained by the Geological Survey indicates the proximity on the one hand of the relics of Silurian strata to the Gorran quartzites, and on the other hand the downward succession from the quartzites to the Veryan limestones, cherts, etc., Portscatho, Falmouth, and Mylor Series; so that these divisions are not probably 'Upper

[1] See Notice of Memoir on Tavistock, etc., p. 227.
[2] Journ. Roy. Inst. Cornwall, vii.
[3] Geol. Mag., 1906, p. 33.
[4] C. Reid, *Geology of Mevagissey* (Geol. Survey), 1907, p. 39.

Silurian', but of older Palæozoic age than the Veryan Series, which is regarded as Ordovician by Mr. Howard Fox.[1]

These questions, dealt with mostly in footnotes by the author, are not of great concern in connexion with the main object of his work. With regard to the age of the ore-deposits he states: "That much of the iron oxide, iron and copper sulphide, and oxide of manganese of the Devonian and Carboniferous rocks appears to be pre-granitic in origin. On the other hand there is very little reason for supposing that there was any tin in the rocks before the granite was intruded."

The mode of occurrence of the ore-deposits, the earth-folds and faults, together with the granite intrusions, are described, and full particulars are given of the carbonas, stockworks, and floors. The lode-fillings and modifications in adjacent country rocks, the sources and distribution of ores and vein-stones, the relative ages of elvans and lodes, and the detrital ore-deposits all receive attention.

The area dealt with extends from Ashburton in Devon to the Land's End, and the author gives a general account of each mining district or chief group of mines, with instructive details illustrated by maps, sections, and plans of particular mines, the district of Camborne and Illogan being regarded as "almost equal in importance to all the remainder of the regions taken together". Outlying mineral areas are likewise dealt with, including the Brendon Hill iron-lodes, the Brixham iron-mines, the Upton Pyne manganese-ore, etc. Subterranean water-circulation and thermal waters are also described. There is an Alphabetical List of Mines, with statistics of production; and there are tables of the occurrence of minerals in different rocks and in successive deposits in veins or fissures. A good index completes this eminently practical volume.

II.—Geological Survey of Great Britain.

1. The Geology of the Country around Tavistock and Launceston. By Clement Reid, F.R.S., G. Barrow, F.G.S., R. L. Sherlock, D.Sc., D. A. MacAlister, A.R.S.M., and Henry Dewey, F.G.S. 8vo; pp. vi, 144, with 3 plates and 48 text-illustrations. 1911. Price 3*s*.

A GLANCE at the excellent colour-printed map (Sheet 337, price 1*s*. 6*d*. net) which accompanies this memoir indicates the many important additions made to our knowledge of the country since the 1 inch geological map of De la Beche was published. The contrast is shown in the subdivisions of the igneous and metamorphic rocks in the Culm Measures and valley deposits; at the same time not so many divisions are distinguished on the map as are stated in the table (p. 2) to be so represented. There is no doubt that the area is one of the most difficult in Britain to interpret owing to successive earth-movements prior to and during the intrusion of the granite masses, and subsequently. So that with faulting, irregular

[1] See J. B. Hill and D. A. MacAlister, *Geology of Falmouth and Truro* (Geol. Survey), 1906, pp. 15, 19.

packing, and overthrusting, the true sequence of the several subdivisions in the Upper Devonian is not manifest, nor are the relations clear between Devonian and Lower Culm Measures, nor between the Lower and Upper Culm Measures. The general sequence, however, appears to coincide very fairly with that given by John Phillips from the Upper Devonian Petherwin Group with *Goniatites* and *Clymenia*, to Carbonaceous or Culm Measure shales, shales with limestone, and Coddon Hill chert series; and he observed appearances of some unconformity between the base of the Culm Measures and the Petherwin Group. The extension of the chert beds is well shown on the new map by a bright yellow tint, and they are regarded as probably belonging to the Upper Limestone Shale, a position equivalent to that of the Pendleside Series, assigned to the Coddon Hill Beds by Dr. Wheelton Hind.[1] With regard to the origin of the chert, the authors of the present memoir remark that "the chert seems to be an altered shale of very fine grain, containing a considerable number of radiolaria, but generally without the calcareous foraminifera and other calcareous organisms which must have accompanied them. The preservation of the fossils was apparently due to silicification of the rock at an early date, before the radiolaria had disappeared, but after the calcareous organisms had been removed". In this view the authors differ from Dr. G. J. Hinde and Mr. Howard Fox, who regarded the cherts as "essentially of organic origin".

There is much of interest in the accounts of the volcanic rocks with pillow-lavas in the Upper Devonian of Tavistock and in the Lower Culm Measures of Brent Tor and elsewhere. That some of the igneous areas are complicated enough may be judged from the description of a large road-stone quarry at Newbridge, south-west of Callington. There "in the quarry itself the rocks are seen to be greatly disturbed. At its entrance an outcrop of slate has been converted to spilosite through contact with an intrusive basic igneous rock which appears through the floor of the quarry on the western side. Chert is found in the lava on the eastern side near a small fault. Above the spilosite, on the western side, lava and chert are in juxtaposition, but the junction between them and the slate is a disturbed one. Further in the quarry this lava is found to be a prolongation of the main mass. A little spilosite is found above the lava, but the rest of the quarry inwards consists almost entirely of fresh vesicular lava".

The association of contemporaneous volcanic rocks with the Culm Measure chert is interesting, and suggests to the authors some possible connexion between the submarine eruptions and the silicification before mentioned. The greenstones, the polyphant stone (a serpentinized picrite),[2] the granites and elvan-dykes, and the metamorphic aureole are duly described.

There is no great amount of valley drift, but it comprises gravel, alluvium, and peat, and there is also some hill-peat. Stream-tin and

[1] Geol. Mag., 1904, p. 400.

[2] The paper by Mr. J. H. Collins on Cornish Serpentinous Rocks, Geol. Mag., 1886, p. 366, has apparently been overlooked; see also Collins, Journ. R. Inst. Cornwall, vol. xxiii.

wolfram have been obtained from the alluvial deposits on and near to the Bodmin Moor granite. A full account is given of the various mines of tin, copper, lead, silver, manganese, etc., with plans and statistics. Building-stones, slates (mostly Carboniferous), and other economic deposits are described, and a short account is given of water-supply derived from granite areas.

III.—Geological Survey of Great Britain.

2. The Geology of the Country around Ollerton. By G. W. Lamplugh, F.R.S., J. B. Hill, R.N., W. Gibson, D.Sc., R. L. Sherlock, D.Sc., and B. Smith, M.A. 8vo; pp. v, 93, with 6 text-illustrations and 4 plates. 1911. Price 2*s*.

OLLERTON is situated on the Bunter Pebble-beds of Sherwood Forest, and lies in the northern part of the area represented on the colour-printed map, Sheet 113, accompanying this memoir.

The area is formed almost wholly of Permian and Triassic strata, for there is but a tiny portion of Lower Lias in the south-eastern corner, and the Coal-measures, worked at Warsop, do not appear at the surface, although they extend beneath the entire area probably at a depth which nowhere exceeds 4,000 feet. The map shows the Drifts, but we have never seen a 1 inch sheet with glacial deposits, which shows less Boulder-clay, gravel, and sand. The Trent River on the east is naturally bordered by Alluvium and Valley gravel; there are tracts of tufa in the Alluvium near Caunton and Tuxford, and there are deposits of Blown Sand bordering the Trent and apparently derived from the river flat.

An interesting marine bed is described as occurring above the Top Hard Coal in a shaft at Mansfield Colliery, the most abundant fossils belonging to species which occur below the Millstone Grit. Some differences of opinion are expressed with regard to the relations between Permian and Trias. Mr. Hill sees local indications of unconformity, whereas Dr. Sherlock considers that the upper part of the Permian in the northern district is equivalent to the lower part of the Bunter further south. The Bunter Pebble-beds, which yield a dry sandy soil, extend through that part of Sherwood Forest known as the 'Dukeries', and noted for its beautiful parks and fine timber. The lower portion of the Keuper is termed 'Waterstones', though Lower Keuper Sandstone would seem a more appropriate general term. The Keuper Marls contain gypsum and layers of hard dolomitic sandstone or 'skerries', the outcrops of which are indicated on the map by lines. Rhætic beds occur over a small area, including the *Avicula-contorta* shales and overlying marls and pale limestone that, despite the doubts of Mr. L. Richardson, may reasonably be regarded as representing the White Lias.

We are glad to see attention given to the organic remains (mammals, mollusca, and plants) of the Alluvial deposits, including also human remains and celts. The older Valley gravels do not appear locally to have yielded any fossils, but the authors discuss the changes indicated since the river was established. Economic geology has a useful section on soils and agriculture; there are records of borings and sinkings; and a Bibliography forms the concluding portions of this memoir.

The illustrations of 'Rock-houses' in Bunter Pebble-beds, and of the 'Druid Stone', a cemented mass of gravel at Blidworth, of the quarries in Bunter for moulding-sand and in Keuper Marl for gypsum, are interesting, but in our copy they are poorly printed.

IV.—Faults and Dykes: A Geological Study of the Witwatersrand. By John S. Olver. 8vo; pp. vii, 298, with 62 text-illustrations and 6 plates. London: The Mining Magazine, Salisbury House; Cape Town, J. C. Juta & Co., 1911. Price 21*s.* net.

THIS is an expensive volume, judging from the amount of letterpress and illustrative matter. These are well printed, but the figures and diagrams are not properly numbered and there is no index. The work, however, is one which has important practical applications in the gold-mining area of the Rand, and should be of essential service to those engaged in the economic working of mines and in the development of fresh areas.

The author commences in Part I with descriptions of faults, normal and reversed, and of dykes which may be simple fissures or faults filled with intrusive igneous matter. Various diagrams and calculations are given with respect to fault-movements and slides or slide-thrusts, and he observes that thrust movements on the whole are much greater than the throws of ordinary faults. Attention is called to the importance of observing all phenomena connected with displacements, such as the presence or absence of drag; the effects of tilting on normal faults; the character of the material with which the fissures are filled, as a means of identification; whether water-bearing and if water ceases to flow from higher levels when tapped below; and the relative ages of the disturbances. It is observed that quartzites and bankets are best examined when wet, dykes when dry; that cleaved quartzites are suggestive of the proximity of an important fault. The character and composition of reefs, especially the size of pebbles, are important in identifying particular bands. The author remarks that "There appear to be a few well-attested cases on the Rand in which a dyke has been found to carry an appreciable amount of gold, and it seems not at all improbable that such a dyke would enrich the reefs in contact with it". He concludes, however, "that intrusive igneous matter has played a very small part in the introduction of gold into the banket." Finally, hints are given on mine-sampling.

Part II contains a particular account of the geology of the Central Witwatersrand, illustrated by maps and sections. In his concluding remarks the author states: "There appears, in fact, to be no basis whatever for the traditional belief that the further course of the Rietfontein Reefs must be towards the east. The only local evidence of value points in a north-easterly direction. Whether the author's theory with regard to a northern outcrop of the Main Reef Series is sound or not can only be proved by actual boring operations, but it can be confidently claimed that the balance of evidence at present available is overwhelmingly in favour of the theory." While discussing the views of other observers he does not give a single footnote reference to their publications.

V.—Cambridge County Geographies.

OF this series we have received the volumes relating to Buckinghamshire by Dr. A. Morley Davies (1912), Northamptonshire by Mr. M. W. Brown (1911), and Midlothian (Edinburgh) by Mr. Alex. McCallum (1912). As would be expected, the physical features, geology, and soils of Buckinghamshire are well described, and also illustrated by longitudinal sections and views of quarries. The geological map, as in the other volumes, does not show the Drift deposits, but descriptions are given of Boulder-clay and gravel. The economic uses of the various formations, including greywethers, are noted, as well as the relations of the plants to the soils and subsoils. There are good views of river scenery and an interesting map showing the distribution of streams, and their absence over the higher Chalk tracts; also views of lynchets and of the old 'ridge and furrow' method of draining clay lands.

Northamptonshire has not such an extended series of geological formations, but the map is more detailed than that of Buckinghamshire. Views are given of river scenery and floods, of ironstone workings at Islip and iron-works at Corby, of a stone quarry at Weldon, and the splitting of Collyweston slates. Some Palæolithic and Neolithic implements are also figured.

In the excellent account of Midlothian there is much to interest in a maritime, agricultural, and industrial county. The formations extend from the Ordovician and Silurian of the Moorfoot and Pentland Hills to the Carboniferous of the central valley, with Glacial Drifts and other superficial deposits, as well as igneous rocks. Arthur's Seat is represented in a somewhat sombre view, but a better one is given with the Burns Monument in the foreground. The views of the romantic glens of Roslin and Hawthornden are good. Of the economic products particular mention is made of the coals and oil-shales, building-stones, bricks, and fire-clays. It is also noted that salt-works on a small scale are still in operation for the preparation of salt rock at Joppa and Pinkie Pans between Portobello and Musselburgh.

Later volumes received, all dated 1912, are West London by Mr. G. F. Bosworth, Oxfordshire by Mr. P. H. Ditchfield, and Breconshire by Mr. Christopher J. Evans. The volume on West London, while full of interesting matter, contains a repetition of the more general parts in the same author's "East London", and the section on geology is the same. The district includes St. Pancras, Holborn, Lambeth, and the area to the west. There are good views of Highgate Ponds and Hampstead, and accounts, with pictures, of some of the Museums. An index completes the work. Oxfordshire contains a well-written section on geology, illustrated by good figures of some fossils and view of Malmstone Quarry at Watlington. The red (ferruginous) lands and iron-ore of Adderbury, Hook Norton, etc., are described, also the Stonesfield Slate, various Oolites, and later deposits. An excellent account of the scenery is given.

Breconshire, so spelt (as we are told) by a decision of the County Council in 1910, is for the most part a mountainous county of Old Red Sandstone with Silurian and Ordovician rocks on the north, and a fringe of Carboniferous rocks with Coal-measures on the south. A somewhat brief account is given of the local geology, with a few geological views and others of river scenery. Agriculture is the main industry, and small fruit is now cultivated in some of the valleys. The physical and geological maps are given as of Brecknock.

VI.—The Students' Handbook of Stratigraphical Geology. Second edition. By A. J. Jukes-Browne, F.R.S. 8vo; pp. xiv, 668. London: Edward Stanford, 1912. Price 12*s.* net (post free 12*s.* 4*d.*).

We welcome a second edition of this comprehensive and well-arranged manual, of which the former edition was noticed in the Geological Magazine for 1902, p. 279. The book has naturally grown in size and in number of illustrations, and it is noteworthy that the author has not introduced any photographic plates. These render some modern works more attractive as picture-books; they are useful in the matter of scenery and rock-structure, but not usually so clear and instructive as regards the stratigraphical arrangement. The author has brought his work well up to date in giving the leading subdivisions of the geological formations in the British Isles, and in various parts of Europe, so that, apart from its essentially British interest, it forms a work of reference on European stratigraphical geology that will be of the greatest service to students and teachers. In the vexatious task of revising the names of fossils according to the latest changes, the author acknowledges the special help of Mr. Henry Woods. We fear, however, that both in palæontological names and in the use of certain chronological terms (such as Valentian, Salopian, and Downtonian) there never will be entire uniformity among geological writers.

The term Charmouthian for part of the Lias (pp. 383, 387) is used for the Middle Lias zones of the Ammonite genera *Paltopleuroceras spinatum* and *Amaltheus margaritatus*, whereas on p. 405 the term is taken to include also the Lower Lias zones of *capricornus* and *armatus*. This is unfortunate and no improvement. As a matter of fact the term is inappropriate as no Middle Lias (as above defined) occurs in the cliffs at Charmouth. If used at all the term should be applied to the Lower Lias clays (zones *obtusus* to *capricornus*). Mr. Jukes-Browne reintroduces his terms of Glevanian, Clavinian, and Vectian, but like new names of fossils they add but a burden to the student who is bound also to learn the older and more widely known names. The Bovey Beds are now placed in the Miocene. The Pleistocene Series is taken to include all deposits (subsequent to Pliocene) "which are older than those containing metal implements of human manufacture". This again is not the usual grouping; the term Holocene is now largely applied to deposits from Neolithic times to the present day, and should at any rate have been so noted.

The extended bibliographical references have been carefully selected, and form an important feature in the volume.

VII.—The Natural History of Clay. By Alfred B. Searle. 8vo; pp. viii, 176. Cambridge: University Press, 1912. Price 1*s.* net.

THIS little work is issued as one of "The Cambridge Manuals of Science and Literature", and will be of most service to those studying the practical uses of clay. As the author remarks, it is difficult to give a definition of clay, especially when it includes such diverse deposits as kaolin, fuller's earth, marl, loam, shale, slate, fire-clay, and boulder-clay. He rightly decides that clay is "not a mineral but a rock", irrespective of any legal significance of the term 'mineral',[1] but ultimately he remarks (p. 150) that "In so far as it can be isolated *true clay* appears to be an amorphous, or practically amorphous, material which may under suitable conditions crystallize into rhombic plates of Kaolinite".

He gives an account of the colours, chemical composition, and physical characters of various clays, but finds fault with the geologists' use of the term 'boulder-clay'. He would like the term "restricted to the plastic portions and not including pockets of sand, gravel, and other non-plastic materials". In practice he would soon find the impossibility of any such restriction. He gives an analysis of boulder-clay, presumably of the clay matrix, but the subject reminds us of a chemist who asked a geologist about an analysis of boulder-clay, and the reply was, "you might as well ask for the analysis of a house." We had not heard of certain Palæozoic or Primary Shales being termed 'marls' when soft and friable, nor are the Thames Valley brickearths as a rule 'natural *marls*'. The geological portions of this work are weak in many respects. The most typical deposits of Kimeridge Clay are not in Huntingdonshire, the 'Kellaway blue clays' are not of freshwater origin, nor are the differences in the Wealden clays "more in the fossils occurring in them than in the characters of the clays themselves", they depend mainly on stratigraphical position.

In another edition the Table of "Chief Clay Rocks (arranged geologically)" should be amplified, as "Oolitic (brick and tile clays)" and "Cretaceous (cement clays, brick clays)" contain no useful information; Oxford Clay, Gault, etc., should be given. Elsewhere in the volume more stratigraphical particulars are recorded, but they are meagre. Watcombe terra-cotta clay should have been mentioned among the Permian clays, and there is some confusion (pp. 54, 131) in the references to Triassic marls, and the Etruria Marl Series in the Upper Coal-measures of North Staffordshire.

VIII.—A Geological Excursion Handbook for the Bristol District. By Sidney H. Reynolds, M.A., F.G.S., Professor of Geology in the University of Bristol. 8vo; pp. 224, with 50 text-illustrations. Bristol, J. W. Arrowsmith, Ltd.; London, Simpkin, Marshall & Co., Ltd. Price 3*s.* 6*d.* net.

WE do not doubt that this little volume will prove a useful and very instructive guide to all interested in the geology of the country around Bristol. The area is naturally limited on the west by

[1] See decision respecting the question "Is China Clay a Mineral?", Geol Mag., 1908, p. 564.

the Bristol Channel and the Severn as far north as Tites Point, but inland the descriptions take in Frocester near Stroud, and thence southwards they include Bath, Bradford-on-Avon, Westbury, and the country near Frome, together with the Mendip Hills.

In this highly interesting district a great number of geological formations are met with from the Silurian to the Upper Oolites, with sundry igneous rocks, and Post-Tertiary deposits including those of caverns and raised beaches.

The story of the great physical changes indicated by the strata and associated volcanic rocks is briefly and pleasantly told in the Introduction by Professor Lloyd Morgan, whose essay touches on the poetic aspect of geology and is well calculated to stir up enthusiasm.

Then follow the practical instructions on excursions, aided by useful diagram-sections and maps, all indicative of the author's wide and exceptional knowledge of petrography, stratigraphy, and palæontology.

Of late years special attention has been given to the Carboniferous Limestone, as well as to the volcanic rocks of Mendip and of the coast near Weston-super-Mare. The particulars given of the zonal divisions in the Carboniferous will be appreciated, but for the sake of the younger students it would have been well to indicate the classes of organisms to which belong such forms as *Caninia*, *Seminula*, *Syringothyris*, etc. The presence of arborescent markings in the Carboniferous Limestone is interesting; the author refers to them as 'Cotham Marble' bands, but here the use of the term Landscape Marble would have been better. Cotham Marble has its own horizon in the Rhætic Beds, and if there had been good local sections at Cotham the author would no doubt have guided us to them. He wisely, however, gives no account of temporary exposures. The famous section at Aust gives the best section of the strata. The Lias and Inferior Oolite also are seen in various noted localities, and those who are interested in *hemeræ* will find an enumeration of thirty-one for their guidance. They are, however, for the specialist, and the student will find the ordinary groupings duly indicated. The names Upper and Lower Lias might have been introduced on the Table II.

IX.—Brief Notices.

1. Geological Map of Central Europe.—A small colour-printed map of this region, on the scale of 100 miles to 1 inch, has been published by Mr. Stanford (1911), price 5*s*. It shows the leading geological systems and intrusive igneous rocks, under twelve tablets: Miocene and Pliocene, Eocene and Oligocene, Carboniferous and Permian, Upper Silurian and Devonian, being respectively grouped together. Certain pre-Cambrian or Archæan rocks are classed as 'Brioverian', which seems too local a term for such a map, while another tablet indicates "Crystalline schists and gneiss". The topography is clear, showing the rivers, mountains, and principal towns, but no railways, and the colours for the most part are distinctive, although here and there, in the smaller areas, numbers printed on map and tablets would have been an advantage. The map includes Dublin, Hull, and Kiel on the north, Warsaw and Belgrade on the east, Brindisi, northern

Sardinia, and Madrid on the south. It will therefore prove a very handy guide to the geological traveller, and be useful also for general reference.

2. Mineralogy. By F. H. Hatch, Ph.D., etc. Fourth edition, entirely rewritten and enlarged. pp. ix + 253, with 124 illustrations. London: Whittaker & Co., 1912. Price 4*s*. net.

AFTER passing through three editions without change this little manual has been entirely rewritten, and in its latest form is twice its original bulk. In the first part, dealing with the properties of minerals, the chapter on physical properties has been considerably enlarged, and a good account of the phenomenon of refraction is included. The use of a different notation for elasticity axes might have been preferred, however; confusion with the crystallographic axes may arise through the employment of small Old English characters of the same notation. It may be noted also that "statical changes", mentioned in connexion with pyro-electricity (p. 57), should evidently be read as "statical charges". A list of the more important mineral species, classified according to chemical composition, makes a useful addition.

A much fuller account of the rock-forming minerals is to be found in the second or descriptive portion, and the chapter on ores is almost three times its original size. Considerable attention seems to have been paid to the preparation of this book, and the student of elementary mineralogy would do well to provide himself with a copy.

3. *Belemnitella mucronata* Chalk of Simbirsk.—The geological library of the British Museum has received from the Ghornoi Institute of St. Petersburg a copy of the rare volume "Nauchno-istorich. Sbornik. — 1873", which contains Laghusen's paper on the *B. mucronata* chalk of Simbirsk, with its four beautiful plates. One might easily fancy oneself dealing with a typical Norwich fauna. Considering the Ghornoi Institute had but three copies of the work left, their action in presenting one to the British Museum (Nat. Hist.) is most generous. It is of much service and will be highly appreciated.

4. Topographic Map of Meekatharra, Western Australia.—This map, on the scale of 40 chains to an inch, and published by the Geological Survey of Western Australia, is the work of Mr. H. W. B. Talbot, Assistant Field Geologist, and represents part of the Murchison Goldfield.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

February 28, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "Late Glacial and Post-Glacial Changes in the Lower Dee Valley."[1] By Leonard Johnston Wills, M.A., F.G.S., Fellow of King's College, Cambridge.

[1] Communicated by permission of the Director of H.M. Geological Survey.

After pointing out that the district where the River Dee leaves its deep valley in the Welsh hills and enters the lower ground occupied by the Coal-measures is a critical one in connexion with its post-Glacial history, the author briefly describes the composition and local distribution of the Irish Sea and Welsh Drifts.

The second part of the paper deals with post-Glacial changes in the topography of the Dee Valley. The term 'post-Glacial' is here applied to events that occurred after the period of maximum glaciation. Many of the changes dealt with may have originated in late Glacial times.

In the Llangollen district the modifications are dependent on the serpentine course of the whole valley. Glacial phenomena have led to the cutting of overflow channels across the necks of the loops, at great heights above the river. Two of these have become permanent courses of the Dee, with the result that deep gorges have been formed across the rocks while the deserted loops have been left like gigantic oxbows.

The other diversions appear to be due to the fact that the post-Glacial course of the river was determined by the surface configuration of the Drift, and has since been excavated into the solid rock at places where it never flowed before. They are, in fact, cases of superimposed drainage.

An unimportant diversion at Argoed (near Trevor) is described, in which the river takes a longer course than in pre-Glacial times. The most notable change, however, occurs near Cefn, and involves the cutting of an entirely new course, some ten miles long, between that locality and Eyton near Overton. Details of this gorge are given, and a suggestion is put forward to explain why the river took this course.

The general direction of this, the present, Dee valley is easterly. The pre-Glacial course has been traced southwards with some precision from near Cefn to Chirk, and then with less certainty in a more south-easterly direction for a few miles. In that direction the Drift is so thick that it has been found impossible to trace the former course until it rejoins the deep buried valley which Dr. Strahan discovered in the neighbourhood of Chester. The author's observations have proved the continuation of this buried valley southwards nearly to Bangor-on-Dee. Near here, at Roden's Hall, the rock-surface is 30 feet below sea-level.

The southerly bend of the pre-Glacial valley near Cefn to Chirk, and then towards Whittington, suggests the possibility of a confluence of the Severn and the Dee, and this is shortly discussed.

It is shown that formerly the River Ceiriog joined the pre-Glacial Dee at Chirk, and that its present course below Chirk is post-Glacial. The gravels of this valley suggest that the post-Glacial drainage always followed this course. It is shown, however, that the Morlas Brook, which is now a tributary of the Ceiriog, was not always so, its early post-Glacial course having been to the Severn.

The slope of the pre-Glacial valley-floor and the uplift which is indicated by the buried valley, now many feet below sea-level, are briefly discussed.

2. "The Glen Orchy Anticline (Argyllshire)." By Edward Battersby Bailey, B.A., F.G.S., and Murray McGregor, M.A., B.Sc.

The district described stretches from the head of Loch Awe to Beinn Achallader, and is the south-eastern continuation of the Fort William, Ballachulish, and Appin country dealt with by one of the authors two years ago. The subject is the tectonics of the schists.

In the centre of the district a diagrammatic recumbent fold, of at least two miles in magnitude, is exposed to view in Beinn Udlaidh, in the heart of a gentle anticline, to which the name of the Glen Orchy Anticline is fittingly assigned. Around the western, southern, and eastern rim of this anticline, are found rocks which lie upon a structurally higher level than the Beinn Udlaidh Fold. A limestone which occurs among these rocks is correlated with the Ballachulish Limestone, and is believed to mark the core of the great recumbent Ballachulish Fold, everywhere in this district underlain by the Ballachulish Slide (fold-fault). Incidentally this interpretation involves a displacement of at least twenty-four miles along the Ballachulish Slide. Finally, an important inversion of the Ballachulish Limestone and Slide is discussed in connexion with a description of the Beinn Doirean and Beinn Achallader range of mountains on the east side of the Glen Orchy Anticline.

March 13, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Glacial Origin of the Clay-with-Flints of Buckinghamshire, and on a Former Course of the Thames." By Robert Lionel Sherlock, D.Sc., A.R.C.S., F.G.S., and Arthur Henry Noble, B.A., F.G.S.

The paper is founded on observations made during the mapping of some 260 square miles on the 6 inch scale, in Buckinghamshire, Berkshire, Hertfordshire, and Middlesex.

The superficial deposits are divided into Clay-with-Flints with the associated Gravelly Drift and the Fluvio-glacial Gravels. There are, in addition, certain high-level gravels, older than any of these, and also the river gravels and alluvium of the present streams, none of which deposits are dealt with in the paper.

Evidence is given to show that the Clay-with-Flints and Gravelly Drift were formed by an ice-sheet which came from the north or north-west over the Chiltern Hills. Only the clean upper layers of ice surmounted the escarpment, and this produced the Clay-with-Flints and Gravelly Drift from the 'head' (Chalk and Eocene waste), which had been accumulating for ages.

At that time the Thames flowed, at the foot of the Eocene escarpment, from Bourne End through Beaconsfield and Rickmansworth to Watford. The ice-sheet blocked the river-channel between Bourne End and Rickmansworth about the time of maximum cold, and diverted the Thames southwards at Bourne End. The river beyond Watford was further blocked by the Eastern Drift, which has left

Boulder-clay near Hatfield and at Finchley. The section of the river between Rickmansworth and the Eastern Drift had its direction of drainage reversed, and the water escaped at Rickmansworth by a new channel which became the Colne.

On the melting of the ice, Fluvio-glacial Gravels (Plateau Gravels of some writers) were left over a great area. These gravels are composed chiefly of Eocene and Cretaceous materials derived from the Gravelly Drift, but also contain Bunter pebbles which have been brought down the Thames. The Bunter pebbles are particularly abundant in a band between Bourne End and Watford; to the south only a few, presumably washed out of the band, are found. They are believed to show that the Thames in times of flood returned to its former course.

The floods from the melting ice, added to the waters of the Thames and Colne, produced, by denudation of the Eocene clays, the great flat through which the Thames now flows, east of Maidenhead, and which, opposite Iver, is 8 miles wide.

After the retreat of the ice, the Wye and Misbourne extended their channels over the Fluvio-glacial Gravel flat, and some other small streams were formed.

2. "Some New Lower Carboniferous Gasteropoda." By Mrs. Jane Longstaff (*née* Donald), F.L.S. (Communicated by Dr. G. B. Longstaff, M.A., F.G.S.)

Eight species of Gasteropoda are described, six being regarded as belonging to five new genera or sub-genera, the others representing *Pithodea*, De Koninck, which has not previously been recorded from the British or Irish Carboniferous Limestone. Among others, the shell of *Pleurotomaria* (*Tropidostropha*) *Griffithi*, M'Coy, is described in detail, and the nature of the fine pitting of its external surface is discussed.

II.—Mineralogical Society.

March 12, 1912.—Professor W. J. Lewis, F.R.S., President, in the Chair.

Dr. G. F. Herbert Smith and F. N. A. Fleischmann: On the Zeolites from Killyflugh and White Head, County Antrim. Chabazite occurs in three different kinds of crystals and gmelinite in two, and the former is also found pseudomorphous after calcite. Analcite occurs in clear trapezohedra, and natrolite in fine needles. The character of the occurrences was described.—Dr. J. Drugman: On Quartz Twins. Further specimens of bipyramids twinned on the primary rhombohedron from the Esterel, France, were shown, thus establishing this mode of twinning, which was first described by Q. Sella in 1858. From the same localities were shown also bipyramids twinned on ξ $(11\bar{2}2)$, in which, too, the prism is absent and there is no flattening perpendicular to the twinning plane as in the Dauphiné and Japanese specimens.—T. V. Barker: Note on the Optical Properties of Mercuric Iodide. Preliminary determinations by means of two 30° prisms gave 2·746 and 2·447 as the values of the ordinary and extraordinary refractive indices sodium, and 2·566 and

2·357 for lithium light, the degree of accuracy being about 0·002. More accurate values are anticipated when better prisms have been prepared, but the results so far obtained suffice to show that the double refraction and colour dispersion are remarkably large in amount.—Arthur Russell: Notes on the Minerals and Mineral Localities of Shropshire. The occurrences of thirty-two species, excluding rock-forming minerals, were described. Calcite was obtained at Snailbeach Mine, Minsterley, in splendid crystals of varied habit, among others being large, pale mauve, rhombohedra twinned on *c* (111), and opaque, white, prismatic crystals twinned on *r* (100). Very large crystals of barytes and fine crystals of calcite came from Wotherton Mine, Chirbury. The occurrence of pyromorphite and witherite at several localities was noted.—Dr. Emil Hatschek exhibited a series of specimens and lantern slides illustrative of some reactions in gels. An inorganic gel (silicic acid) was used, and the compounds resulting from the diffusion in it of several solutions were shown; there is a tendency to banding in the upper part of the precipitate, while spherulitic growths were obtained in nearly every case. Mr. W. Campbell Smith exhibited a spherulitic dolerite from Vryheid, Natal; the rock was interesting on account of the size and beauty of the spherulites, which were revealed on weathered surfaces.

III.—Zoological Society of London.

March 19, 1912.—S. F. Harmer, Esq., M.A., Sc.D., F.R.S., Vice-President, in the Chair.

Mr. T. H. Withers, F.G.S., read a paper, communicated by Dr. W. T. Calman, F.Z.S., on "Some early Fossil Cirripedes of the genus *Scalpellum*".

Attention was drawn to the form of the carina of the geologically older species of *Scalpellum*, and it was shown that the earliest forms known resembled more closely the carina of *Pollicipes*, from which *Scalpellum* is considered to be derived. An almost complete capitulum of the Albian *Scalpellum arcuatum* was described, together with some scales of the peduncle, and a restoration was given. This specimen was important because, with the exception of a few detached valves found in the Aptian (Lower Greensand), it was the oldest known fossil Cirripede that could with certainty be referred to the genus *Scalpellum, sensu lato*. *S. arcuatum* was considered to be an ancestral form of the group of almost exclusively deep-sea species, which Dr. P. P. C. Hoek had separated as a sub-genus under the name *Arcoscalpellum*, and its relationship to other species was discussed. *S. trilineatum* was also redescribed.

CORRESPONDENCE.

A HUMAN SKELETON IN GLACIAL DEPOSITS NEAR IPSWICH.

Sir,—My attention has been drawn to two communications[1] in the April Number of your Magazine dealing with the human skeleton I discovered here in October of last year.

[1] See Geol. Mag., April, 1912, pp. 164 and 187.

The points raised by your correspondent, Professor McKenny Hughes, F.R.S., as to the impossibility of being able to recognize after a period of years where ground had been disturbed by a grave having been dug, and his statement that the material which occurred over the bones was not Boulder-clay, are very important and call for the fullest investigation. Your other contributor, Mr. George Slater, F.G.S., who quotes very fully the reports of Mr. W. Whitaker, F.R.S., Mr. John E. Marr, F.R.S., Professor A. Keith, and those of us who saw the bones removed, makes a curious omission in that he gives no detailed reference to the report which he himself gave me in reference to the section in Messrs. Bolton and Laughlin's pit where the skeleton was found.

This report, dated October 21, 1911, and signed by Mr. Slater, is before me as I write, and contains the following paragraphs:—

"As the bones had been removed and a 'nitch' cut down from the top of the pit to a depth of about 4 feet a clear section was shown, but of course there was no means of ascertaining the exact condition of the material removed. *Judging from the section now exposed this portion of the pit varies in no way from other parts of the section, and shows a clear and undisturbed section of weathered Boulder-clay over the calcareous sands in which the remains were found.*

"There is no reason to doubt that the sands and gravels are derived from glacial material, containing as they do derived Jurassic material, *and the Boulder-clay is part of the large sheet exposed so well in the neighbouring pit further to the east of Henley Road.*"

This lucid statement was the result of a very careful examination of the section by Mr. Slater, who has known and visited this pit for years. Yet I find he states on p. 165 of your Magazine that "The general section on this side of the pit [the side on which the skeleton was found] is extremely unsatisfactory", and I am left wondering as to why the section under discussion has so suddenly presented itself to him in such an unsatisfactory aspect.

I also notice that on p. 166 he states that the plateau half a mile to the east of the site where the remains were found "reaches a height of about 160 feet" and that this "gives a gradient of roughly *fifty feet* in half a mile" (the italics are mine). This, however, is incorrect, as my friend Mr. Henry Miller, M.I.C.E., County Surveyor for East Suffolk, has lately taken the levels for me, and these show that the surface of the ground above the spot where the bones occurred lies at a level of 129·01 O.D., and the highest point to the east, half a mile away, is 155·24 O.D.

Thus the gradient in half a mile is roughly 26 feet, not 50 feet as stated by Mr. Slater.

J. Reid Moir.

12 St. Edmund's Road, Ipswich.
April 10, 1912.

All Communications for this Magazine should be addressed—

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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. VI.—JUNE. 1912.

ORIGINAL ARTICLES.

I.—Radiolaria-bearing Rocks in the East Indies.

By J. B. Scrivenor, M.A., F.G.S.

Having read with great interest Mr. E. E. L. Dixon's remarks on the Radiolarian cherts of Gower in the November number of the Quarterly Journal of the Geological Society,[1] I am tempted to offer some notes on the occurrence of similar rocks in the Malay Peninsula and Archipelago, where Radiolaria-bearing rocks are known to be widespread.

The idea that Radiolarian cherts are not necessarily evidence of deep-sea conditions has been steadily growing for a long time, but no one, as far as I am aware, came to close grips with the problem of their origin in shallow water until Mr. Dixon read the paper referred to (I note that the date of reading was March 9, 1910). The theory of a Radiolarian 'lagoon-phase' is the first serious attempt to explain how Radiolarian cherts came to be formed in shallow water.

The foundations of the 'deep-sea' hypothesis having been undermined, it is only natural to inquire if, after all, any known outcrops of Radiolarian rocks are evidence of deep-sea conditions apart from the Barbadian rocks. An extremely interesting paper on this subject was published in 1909 by Professor Molengraaf concerning widespread Radiolarian rocks in Central Borneo, which Professor Molengraaf believes to be oceanic deep-sea deposits.[2] This paper is supplementary to a previous publication, and in order to appreciate its full significance we must go back some years. In 1902 Professor Molengraaf published the results of his explorations in Central Borneo during 1893–4.[3] In this volume the 'Danau formation' is described.[4] It comprises diabase-tuff, diabase-porphyrite, quartzite, chert, jasper, hornstone, clay-slate, and sandstone, the leading rocks being silicified and partly serpentinized diabase-tuff and jasper.[5] The jasper and hornstone were found to contain many Radiolaria, described by Dr. G. J. Hinde in an appendix. Their examination led to the conclusion that the rocks

[1] "The Carboniferous Succession in Gower, Glamorganshire, etc.": loc. cit., vol. lxvii, pp. 511–31, 1911.

[2] G. A. F. Molengraaf, "On Oceanic Deep-sea Deposits of Central Borneo": Proc. Roy. Acad. Amsterdam, vol. xii, pp. 141–7, 1909.

[3] *Geological Explorations in Central Borneo*, English edition, London, 1902.

[4] pp. 414–21.

[5] Op. cit., p. 414.

were pre-Cretaceous and probably Jurassic, and Professor Molengraaf was of the opinion that the presence of the Radiolaria, combined with the great extent of the beds containing them, at least 230 kilometres, stamped those beds as deep-sea deposits. Professor Molengraaf, however, is careful to say that the presence of pelagic organisms alone is not conclusive proof of oceanic deposits, "for we know that in certain localities close to the coast where, through peculiar conditions, the deposition of terrigenous materials on the ocean floor was entirely or almost entirely prevented, even at a short distance from the shore, deposits are found which may be composed exclusively of remains of pelagic living organisms." These conditions were thought too unlikely to extend for 230 kilometres. On p. 418 Professor Molengraaf says in a footnote that the sandy shales and clay-slates are too much folded and disturbed for him to say with certainty whether they lie on top of or below the chert, but they appeared to be above it. Finally, after sketching the extent of the Danau formation, Professor Molengraaf refers to some deposits in Sambas, a province of West Borneo, with the same trend as the Danau formation and comprising a complex of cherts.[1] He adds: "Should the cherts of Sambas prove to be of the same age as those of the Danau formation, Radiolaria will doubtless be found in them if searched for."

In 1904 Mr. Wing-Easton's work[2] on part of West Borneo, including the greater part of Sambas, was published. Radiolaria were found in Upper Triassic, Jurassic, and Cretaceous rocks, many being located in Sambas, but the rocks containing them are not described as cherts as understood by us. Thus, on p. 25 we find in connexion with the Upper Trias: "On the other hand there are in the vicinity of the quartz-porphyries hard beds rich in silica and often with Radiolaria, which must be explained as ashy deposits of the above-named eruptive rocks, and which are very like quartzites when light-coloured or 'kieselschiefer' when dark." These Upper Triassic beds are referred to again on p. 233. On pp. 271, 272, and 275 Jurassic rocks with Radiolaria are mentioned. It is stated that Radiolaria occur in a hard rock which can only be determined as a 'kieselschiefer'. No mention is made of 'hornstein' or 'radiolarienjaspis' except in reference to Professor Molengraaf's rocks (p. 40).[3] The other Jurassic rocks containing Radiolaria are marl and limestone. Among the Cretaceous rocks Radiolaria were found in marl, limestone, siliceous propylite-tuff, and *sandstone*. The most important remarks, however, that Mr. Wing-Easton makes about the Radiolaria-bearing beds are to be found on pp. 40 and 41, where it is emphatically stated that the Jurassic and Cretaceous beds were deposited in shallow water near a coast, and the same view is held, apparently, for the Upper Triassic rocks.

Nevertheless, Professor Molengraaf in his 1909 paper does not qualify his previously expressed views about the deep-sea origin of

[1] p. 421.

[2] "Geologie eines teiles von West Borneo": Jaarb. v. h. Mijnwezen in Neder. Oost-Indië, Weten. Gedeelte, 1904.

[3] Verbeek, however, uses 'kieselschiefer' for chert. See below.

the Central Borneo cherts and hornstones, but produces fresh evidence to show that the Radiolarian rocks extend eastwards for 650 kilometres and cover about 40,000 square kilometres, the composition of the cherts and hornstones remaining perfectly constant throughout. In the map accompanying this paper the Radiolarian rocks are shown striking towards the southern part of Sambas, where Mr. Wing-Easton found Upper Triassic, Jurassic, and Cretaceous Radiolaria-bearing rocks. One would not expect, therefore, to find such divergent views regarding the origin of the Radiolarian rocks in Central and West Borneo, but the difference of the lithological characters of the rocks described by the two authors is so evident that it is difficult to believe that the West Borneo rocks are really an extension of those in Central Borneo.

Another instance of Radiolarian chert being considered evidence of deep-sea conditions is afforded by a rock found in the island of Billiton and described by Dr. Hinde.[1] Dr. Hinde declares for deep-sea conditions on the palæontological evidence, but in the text Dr. Verbeek gives some significant information regarding this rock.[2] It came from the bed-rock of a certain mine, and occurred as a bed about half a metre thick between sandstones and clay-slates.

My own experience of Radiolaria-bearing rocks in the East Indies has been in the Malay Peninsula and in Sarawak.

In the Malay Peninsula there is a series of rocks that I have called the Chert Series, consisting of chert beds with Radiolaria, too poorly preserved to be of homotaxial value, and very fine-grained shales. These shales are sometimes light grey or yellow in colour, and the chert is sometimes green or bright red like jasper, but a common feature of both chert and shales is the abundance of carbon. In the shales this is easily recognized, but in both shales and cherts it has been separated from the other rock constituents and proved to be carbon. In both rocks it has acted as a precipitant of metallic sulphides, and I have a specimen showing beautiful little casts of Radiolaria in pyrite.[3]

Another point that requires more than a passing mention about the Radiolarian cherts of the Peninsula is that where the best exposures occur, namely in Ulu Pahang and in Kedah, they are close to large outcrops of quartzite and conglomerate. They also occur, however, on the Pahang River associated with lavas and ashes.

At first sight it might be supposed that the cherts and accompanying shales are so closely connected with the arenaceous rocks, which have yielded marine fossils, as to be part of one big series comprising both cherts and quartzite, the one conformable to the other, but although this would not be very surprising in the light of

[1] R. D. M. Verbeek, "Geologische Beschrijving van Banka en Billiton," Appendix 1 by Dr. G. J. Hinde, pp. 223–7: Jaarb. v. h. Mijnwezen in Neder. Oost-Indië, Weten. Gedeelte, 1897.

[2] p. 92.

[3] These rocks and their relation to other rocks are discussed in *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, ch. ix and xii, pls. v–vii, xiii, obtainable at the Malay States Information Agency, 88 Cannon Street, E.C.

experience elsewhere there are good reasons for supposing that the arenaceous rocks are separated from the cherts by an important unconformity. The evidence for this is as follows: The conglomerates contain abundant pebbles of chert identical with that in the Chert Series. It might be argued that these pebbles come from still older chert beds that are not visible on the surface now, but pebbles of the volcanic rocks with which the cherts are known to be associated on the Pahang River have also been found in the conglomerate. This points to the Chert Series as the source of the pebbles; and not only had the chert time to consolidate before it was included in the conglomerate, but some of the chert became traversed by veins before being denuded and rolled into pebbles. These facts indicate a considerable break in the record unless we assume, against all available information, that Radiolarian cherts can be deposited and consolidated with great rapidity. There is, moreover, a piece of negative evidence against a close connexion between chert and quartzite, which is that in the biggest outcrop of the quartzites and conglomerates, namely that stretching through the centre of Pahang, no chert has been seen *in situ*. Of course, it may be there nevertheless, but its apparent absence is worth mentioning.

The connexion of the Pahang cherts with volcanic rocks is interesting when one considers the arguments put forward lately by Mr. Dewey and Dr. Flett to supply a possible explanation of the association of Radiolarian cherts and spilites.[1] No evidence has been noticed yet of the albitization of the Pahang lavas, but it is conceivable that emanations from these eruptions, which were mostly submarine, supplied sufficient silica for a flourishing growth of Radiolaria without producing albitization. In Kedah, however, I cannot point to volcanic rocks associated with the chert as a possible explanation of the formation.

In Sarawak the Radiolaria-bearing rocks that I have seen are associated with Middle Oolite limestones and marls,[2] and also with shales that are probably not far removed in age from the limestones and marls. The Radiolaria were found in chert nodules in the limestone, in chert from a calcareous conglomerate, in indurated shales, and in a nodule in shale. The chert occurs in much the same way as flint in chalk, and contains but few recognizable Radiolaria. Some of the indurated shales, found as included fragments in an igneous rock, contain calcite and were probably calcareous shales or marl originally. Radiolaria are common in these fragments. At Santubong, however, on the coast, a few Radiolaria were found in beds of indurated shale associated with beds of sandstone and an occasional bed of ash. Thin sections do not show any reason for supposing that the indurated beds were originally ash of very fine grain.

The nodule containing Radiolaria was found in shale on the Sarawak River at the landing-place for the Bau gold-mines (Bau *penkalan*).

[1] "British Pillow-lavas and the Rocks associated with them": Geol. Mag., 1911, pp. 244–6.

[2] R. B. Newton, Geol. Mag., 1897, p. 415.

It suggests a septarian nodule, but is dull black in colour, and in section shows a brown isotropic base crowded with Radiolaria, sponge spicules, and pyrite. The Radiolaria are mostly calcite casts, but some are partially replaced by pyrite.

Comparison of the above-mentioned Rocks.

Apart from the Radiolarian nodule in shale on the Sarawak River, the origin of which I am at a loss to explain, it would appear that the rocks in Sambas and the rocks in Sarawak containing Radiolaria were deposited under similar conditions, and probably in the same sea, not far from the coast. None of the Sarawak rocks, however, excepting the nodule, can be cited as examples of rocks composed chiefly of Radiolaria. They are not Radiolarian rocks, but rocks containing some Radiolaria, mingled with abundant other organisms in the case of those associated with the limestones.

This, however, is not the case with the Central Borneo and Peninsular cherts, which are distinctly Radiolarian rocks. Professor Molengraaf claims that those in Central Borneo are oceanic, abyssic sediments, but as regards those in the Peninsula I do not see any good reason to believe that the cherts were laid down in an abyss of the ocean, but think rather that a sudden change in conditions apart from depth led to the establishment of a flourishing colony of siliceous-shelled organisms in a sea where hitherto limestone rich in corals and Cephalopods and other calcareous shells had been forming. These cherts are not silicified limestones.

On comparing these two occurrences of Radiolarian rocks, however, we find that there is a considerable lithological difference. Professor Molengraaf[1] thus describes the Central Borneo rocks :—

"The first type is the Radiolarian hornstone, the true Radiolarite. This rock is semi-transparent, hard, brittle, and splintery, and of a colour varying between milkwhite, red, and greenish. It consists of about 97 per cent of silica and is composed almost exclusively of closely-packed tests of Radiolaria, joined together by a siliceous cement. The red-coloured varieties may be called Radiolarian jasper; they contain a small percentage of iron. The tests of the Radiolaria are difficult to distinguish under the microscope in the milkwhite varieties; they can be much better distinguished in the red jasper varieties, but best of all they are preserved and discernible in the greenish varieties of the Long Keloh in the Berau district.

"The second type is an argillaceous chert or siliceous clay-shale, which is always coloured bright red and contains more clay and iron and less silica than the first type. Radiolaria occur in it in variable quantity, but always much less than in the first type.

"The two types pass one into the other quite gradually, and all sorts of intermediate types occur. The distinct stratification of the cherts of the Danau formation is caused by thicker strata of pure Radiolarian hornstone alternating with thin layers which contain more clay and less Radiolaria.

"Both types and all intermediate stages agree in this respect, that

[1] G. A. F. Molengraaf, "On Oceanic Deep-sea Deposits of Central Borneo": Proc. Roy. Acad. Amsterdam, vol. xii, pp. 142–3, 1909.

they do not contain any constituents indicative of a terrigenous origin, and that the organic remains they contain all belong to Plankton organisms with siliceous tests, chiefly Radiolaria.

"In an uncemented state, in which such deposits are still continually laid down on the bottom of the oceans at the present day, the deposits of the first type are called Radiolarian ooze and those of the second type red clay. Radiolarian ooze and red clay gradually pass one into the other, and only differ in the percentage of organic remains they contain. Murray, for instance, places the limit between red clay and Radiolarian ooze at a point where 20 per cent of the deposit consists of tests of Radiolaria."

In the Peninsula, on the other hand, but for a few occurrences near Bentong (Pahang) of red and green chert, the Radiolarian rocks differ markedly from the Central Borneo rocks in being dark grey or black, owing to the abundance of carbon, which is sometimes so thick as to render a thin section almost opaque. The presence of this carbon and the presence of carbon in the limestone referred to above also suggest that whatever its source the limestone and chert have at least one point in common in their mode of formation, and the abundance of carbon in the cherts marks them off as something distinct from the Central Borneo rocks.

The presence of carbon in Radiolarian chert has been noted before, but I have not any recollection of remarks as to its significance. Thus in 1899 Professor T. W. E. David and E. F. Pittman mentioned streaks of carbon in chert found in New South Wales.[1] Dr. Hinde says the supposed carbonaceous matter may be partly ferruginous. Again, in the cherts of the Lower Culm Measures of England, Dr. Hinde and Mr. Howard Fox mention carbonaceous or ferrous material[2] as being in part the cause of fine lamination. These authors also mention rhombohedral casts, found in the cherts. These casts occur sometimes in the Peninsular cherts and in the Billiton chert, the latter of which Dr. Hinde says contains a dust of ferrous or carbonaceous origin.[3]

The origin of the carbon in the Peninsular cherts is doubtful, but it is significant that in some specimens cell-structures have been found believed to be the remains of algæ (*vide* plate vii of the publication on the Geology and Mining Industries of Ulu Pahang).[4] Moreover, the shales associated with the Peninsular cherts cannot be regarded as devoid of terrigenous matter. Like the shales with the limestone they appear to consist of very fine sediment. The presence of Radiolaria in them has only been proved in the case of those rich in carbon.

Anyone who reads Professor Molengraaf's views on the Central Borneo rocks will realize that his case for their being oceanic deposits, in the same sense as the deposits of Barbados are oceanic, is so strong that those who would question it must examine the relations of the

[1] Q.J.G.S., vol. lv, p. 34. [2] Q.J.G.S., vol. li, pp. 629–31, 1895.
[3] Op. cit., p. 223.
[4] I am indebted to Mr. H. N. Ridley, F.R.S., for examining these specimens, and to Dr. Hinde for examining cherts with Radiolaria found in Singapore, but not *in situ*.

rocks in the field. The Peninsular cherts on the other hand, and probably the Billiton chert also, were laid down in a comparatively shallow sea, not out of the reach of terrigenous material. The oceanic Radiolarian rocks are not stated to contain any carbon; the shallow-water Radiolarian rocks are rich in carbon.

Dr. Hinde has also described Radiolaria from Triassic and other rocks in Timor, Rotti, Savu, Ceram, Celebes, Buru, and Mangoli. They are not stated to contain carbon, being light-grey and reddish cherts. Very little is known of their field relations.[1] Dr. Verbeek mentions, however, on p. 320, "*roches triasiques, des calcaires à halobies, des grès et de la lydite à radiolaires*," as occurring on Savu, and on p. 325 says, "*les argiles renferment des radiolaires*". These clays are between marls. This association of rocks certainly points to shallow-water conditions, and it would be interesting to know, in the event of extensive exposures of the Radiolarian cherts being found, if they contain carbon in any quantity.

Origin of the Peninsular Carbonaceous Radiolarian Cherts.

Two suggestions have been put forward to account for the formation of Radiolarian cherts near a coastline: Messrs. Dewey & Flett's suggestion that favourable condition were caused by emanations from a volcanic source, and Mr. Dixon's 'lagoon-phase'. The former cannot be applied to every case; it cannot, for instance, be applied to the Gower cherts. The latter, valuable though it is, lacks, as far as I am aware, the support of known modern examples where Radiolarian beds are being formed.

Messrs. Dewey & Flett have put forward an explanation for some cases, and it remains to find for other cases, such as the Peninsular carbonaceous cherts, where not associated with igneous rocks, a reason for the change from calcareous to siliceous deposits. Whether this change is connected with a lagoon-phase or not, the key to the problem seems to be how sea-water became so charged with silica in solution as to diminish the growth of calcareous organisms forming beds of limestone, and to promote the growth of siliceous organisms. In the absence of volcanic emanations it is just possible that such a condition may be brought about by tropical weathering and rivers discharging into closed or nearly closed seas.

Certain researches that arose out of a question concerning 'laterite', now nearing completion, coupled with previous observations, have emphasized the fact that the most remarkable result of weathering in the Peninsula, as far as widespread effects are concerned, is the removal of silica in solution in enormous quantities. The power of ground-water to dissolve silica is such that quartzite, of which rock there are extensive outcrops, weathers back to sandstone for a considerable depth, and granitic rocks are rendered clayey by the removal of the finer quartz particles and the breaking down of the felspars. There is no evidence to show that the bulk of this dissolved silica does not find its way out to sea, but with it there must go quantities of

[1] *Vide* "Rapport sur les Moluques", R. D. M. Verbeek: édition française du Jaarb. v. h. Mijnwezen in Neder. Oost-Indië, vol. xxxvii, partie scientifique, p. 709, 1908.

lime also, derived from calcareous rocks, also powerfully attacked by ground-water, even under a thick covering of argillaceous and arenaceous rocks. Given a tropical country, however, in which the ground-water acted on siliceous rocks only, a not impossible state of affairs, then it might be that the sea-water would become so charged with silica that siliceous organisms would flourish, while calcareous organisms would diminish.

The most favourable conditions for accumulations of such siliceous organisms to form cherts would be found near or beyond the limit of the finest detritus brought down by the rivers. Within the area of sedimentation we could expect rocks with some Radiolaria to be formed, such as the Sarawak indurated shales and the shales of the Upper Gondwanas near Madras, described by Mr. Coomaraswamy.[1]

This suggestion of the necessary supply of silica having been afforded by tropical weathering is, of course, no less speculative than the other suggestions, but, as a third possible cause of the formation of Radiolarian cherts in shallow seas, it may be of interest. In conclusion I would put forward the two following propositions:—

1. The presence of abundant carbon in Radiolarian cherts appears to be an indication that such cherts are not of deep-sea origin.

2. Large quantities of silica in solution, supplied by tropical weathering of siliceous rocks, may have promoted, or helped to promote, the abundant growth of Radiolaria in shallow seas.

II.—The New Mountain of the Year 1910, Usu-san, Japan.

By E. B. Bailey, B.A., F.G.S.

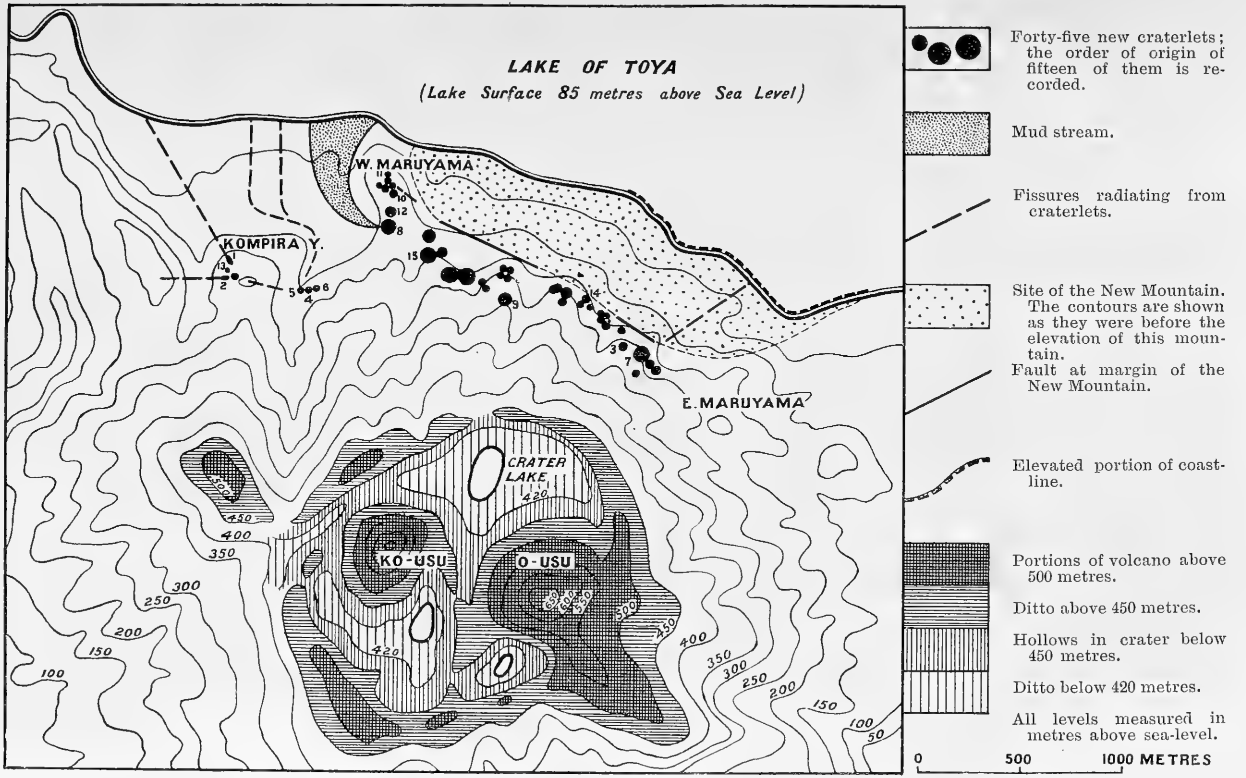
(PLATES XII AND XIII.)

THE writer's attention was directed to Dr. Omori's[2] description of the 1910 eruption of Usu-san through a review which appeared in *Nature* (1911, p. 221) from the pen of Professor Milne, F.R.S. The following pages constitute a *résumé*, rather than an additional review, and are justified on account of the interest of Omori's observations to many geologists who may not find it convenient to consult his original paper. All three figures here published have been redrawn for the purpose. Plate XII is based on a coloured map, and Plate XIII on photographs which have already been reproduced by Professor Milne in his review.

Usu-san is one of a group of volcanoes situated in the south-western peninsula of the island of Yezo, Japan. It is bounded on the south by the sea, and on the north by the Lake of Toya—a circular lake some 10 km. in diameter and 187 m. in depth. The distance of the centre of the volcano from the nearest point of the sea is 4·7 km., and from the lake 2·2 km.; in fact, the situation could not be more convenient than it is for dealing with questions involving measurement of changes of level.

[1] Geol. Mag., 1902, pp. 305, 306.

[2] F. Omori, "The Usu-san Eruption and Earthquake and Elevation Phenomena": Bulletin of the Imperial Earthquake Investigation Committee, Tokyo, vol. v, No. 1, pp. 1–38, pls. i–xiii.



Map of Usu-san, Japan.

The main features in the topography of the mountain are summarized in the map, Plate XII. It will be noticed that two prominent summits, O-usu and Ko-usu, rise within the crater hollow. These two are apparently of prehistoric origin, but are ascribed by Omori to "the pushing up of molten lava mass which solidified during the process". A neighbouring volcano, Tarumai-san, built up a similar lava-dome, 134 m. high, during an eruption which lasted three months of the year 1909. Kompira-yama and the East and West Maru-yamas, on the northern flanks of Usu-san, are also regarded as lava-domes, but evidence in regard to their geological relationships is very meagre, since the whole of the lower portion of the volcano is swathed in soil of great depth. The crater of Usu-san took no part in the 1910 eruption, but Kompira-yama and West Maru-yama were both the sites of active explosions.

There are records of previous eruptions at Usu-san for the years 1663, 1769, 1822, and 1853. In the case of both the 1663 and 1822 eruptions, of which detailed accounts have been preserved, we learn that earthquakes preceded any smoke-explosions by an interval of about three days. The occurrence of warning shocks of this character was a feature once more of the 1910 eruption, and seems to be characteristic of volcanic action in general, at any rate in Japan. In other respects Omori has no analogy to point to between the early eruptions and that of 1910. For convenience of description the phenomena of this last eruption may be grouped under three main headings: (1) earthquakes, (2) explosions, and (3) elevation.

(1) Earthquakes were first felt on July 21, and obtained their maximum frequency during the fifteen hours which elapsed between 6 p.m. on the 24th and 9 a.m. on the 25th. They then fell off rapidly, and in fact were only about half as numerous by the time of the first explosion, 10 p.m. on the 25th. They continued on the decrease the following day also, but thereafter remained irregularly constant during the ensuing months of active eruption.

The earthquakes which preceded the first explosion were not only more frequent than those which followed it, but also more severe. The strongest shock occurred at 3.49 p.m. on the 24th, and the next strongest at 4.39 p.m. on the 25th. A small amount of damage resulted from these disturbances in Abuta, a town 6 km. distant from Usu-san; but, in accordance with the general rule for volcanic earthquakes, neither shock was of really destructive violence, considered, that is, in relation to wooden buildings of Japanese type. The main earthquake penetrated as a sensible tremor to a distance of 60 km. towards the north-east and 140 km. towards the south-west.

(2) As already stated, the eruption proper was initiated by an explosion at 10 p.m. on July 25. The outburst was a single small affair, and took place on the north-west side of Kompira-yama. Ashes and rock fragments were discharged, and a rude crack fashioned in the soft earth of the hillside (numbered 1, Plate XII). Other eruptions from new foci followed at short intervals, some of them enjoying a paroxysmal career of several days duration. By August 10 the number of craterlets had increased to at least twenty-eight. The opening up of fresh orifices continued, though with diminished vigour,

till the end of the year. By November 12 the forty-five craterlets shown on Plate XII had been blasted out. The relative order of formation of a non-consecutive fifteen from among these forty-five was observed, and is shown by the use of numbers on the map. The data thus afforded are sufficiently complete to indicate that there was no simple connexion between the sequence of the explosions and the spatial distribution of the resulting eruptive centres.

All the different craterlets were formed in the thick layer of soft earth to which reference has previously been made. Many of the eruptions proceeded quite quietly and were unaccompanied either by loud detonations or recognizable earthquakes. Ashes and stones were ejected, but never any lava, and 'volcanic fires' are only reported in the case of the first explosion. The majority of the craters had a very brief activity, and after having thrown out clouds of ashes and stones for a few hours, or a day, were then reduced to complete rest. Some, however, persevered for several days and gradually enlarged their diameters to over 200 metres. The spectacle presented by the eruption, as illustrated in Omori's photographs, was often singularly grand with several craterlets in operation at the same time, tossing up smoke and stones 500 m. high into the air. A craterlet at the base of West Maru-yama was somewhat exceptional in its behaviour, for it poured out hot steaming mud after each of its major outbursts; and eventually this mud accumulated to such an extent that it covered a triangular area 800 m. long and 450 m. in base.

Plate XII shows the orderly arrangement of the craterlets and Fig. 1, Pl. XIII, their general appearance. It seems natural to regard them as falling into two divisions, a main group peripheral to the region of elevation and a satellitic group on Kompira-yama. Omori, however, classifies them in three divisions: an arcuate group, concentric with the great crater of Usu-san, and reaching from the flanks of East Maru-yama westwards to the craterlet numbered 5, and two radial groups, the one extending along Kompira-yama and the other along West Maru-yama. There is no need to dwell upon this difference of classification, for it is a mere matter of detail, since Omori is perfectly definite in connecting the origin of the craterlets with the phenomena of elevation which now fall to be described.

(3) The elevation of the New Mountain is the main feature of interest in the 1910 eruption of Usu-san. It first manifested itself in the behaviour of Lake Toya. Thus, in spite of a light rainfall, the waters of the lake rose more than a foot above their usual level in the latter part of July, that is about the time of the commencement of the eruption, and maintained themselves in this position throughout the following month of August. The accompanying rise in the Sobets River, the only outlet of the lake, meanwhile amounted to 2 feet. This apparent increase of the waters of Lake Toya was of a general character and presumably due to a differential upward displacement of some portion of the lake bottom. That local movement of the type required did occur was in fact demonstrated on August 6, when Omori found that a reach of the coastline about a mile long at the foot of East Maru-yama had been elevated nearly a metre out of the water. To study this

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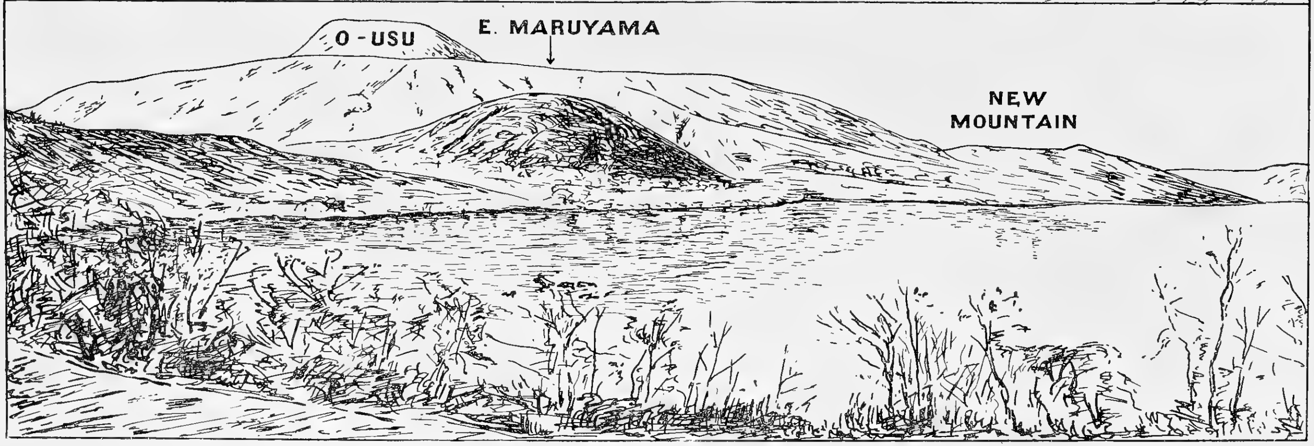


FIG. 1. Fault-face of the New Mountain with tilted trees on top; to the left craterlets formed during the period of elevation.
,, 2. Usu-san with the New Mountain as seen from across the Lake of Toya.

phenomenon more precisely a graduated level-gauge was at once erected in the lake near the east end of the elevated stretch of coast, and two others at convenient points on either side of the disturbed tract. The two control gauges gave concurrent results, so that it was a simple matter to interpret very precisely the differential movement indicated by the instrument situated in between. It is extremely interesting to find that part of the elevation thus determined proved to be of a transient nature. From August 6 to August 21 an elevation of 34·3 cm. was recorded (additional to that which had occurred previous to the former date). A slight drop was then experienced, but the same height was attained once more on August 27. Thereafter a gradual uneven downward movement set in, and by November 10 the lake bottom at the point investigated stood merely 16·7 cm. higher than on August 6.

Meanwhile a large inland tract, about 2,700 m. long and 600 m. wide, was upheaved. At two places along its inner margin it was bounded by a definite fault-face (Plate XII), and it was at the more westerly of these two localities that the elevation was most pronounced (Plate XIII). Here Omori found the inside of the New Mountain defined by a steaming dislocation surface about 94 m. in height and inclined outwards towards the south at angles varying from 30° to 60°. This face, extensive as it was, is said to have consisted entirely of soil with embedded fragments of rock.

The first stages of the elevation passed unnoticed; in fact, it was not till August 20 that the appearance of the New Mountain attracted general attention. The elevation continued to increase till November. From the 8th to the 10th of that month aneroid readings showed a total elevation of 155 m. (510 feet) above the original height, giving, for the time interval of 100 days from the end of July to the commencement of November, an average rate of upheaval of 1·55 m. (5·1 feet) per day.

As in the case of the coastal belt, however, the full elevation of the summit of the New Mountain was not long maintained: aneroid determinations in April, 1911, showed a relapse of some 36 m. (120 feet).

Conclusion. Omori regards the upheaval of the New Mountain as due to the intrusion of magma; the explosions he ascribes to the gaseous emanations from this magma; and the earthquakes which preceded the explosions he connects with the formation of cracks and fractures below the surface permitting of the advance of the molten material. The situation of the craterlets outside the region of elevation is exactly what might be anticipated according to this interpretation, since the boundary fault of the new mountain is inclined outwards in 'normal' fashion. Altogether the Usu-san eruption furnishes a most suggestive picture of what one might expect at the surface during the injection of a laccolite accompanied by fracturing of the upheaved cover. At the same time without further knowledge of the underground relations of the various rock-masses, new and old, liquid and solid, it would be rash, however tempting, to dogmatize in this direction—even on the evidence so carefully observed and described by Dr. Omori.

It may seem ungracious to criticize where one is supplied with so rich a store of valuable information, but there is an omission to which attention may be directed, and that is the absence of any reference whatever to the petrology of Usu-san. It is certainly desirable that a comparison should be made between the material of the lava-domes O-usu and Ko-usu and that which has been intruded beneath the New Mountain; samples of the intrusion may reasonably be looked for in the ashes ejected at the numerous craterlets. In both cases the magma has given evidence of a rather unusually high degree of viscosity, and it would be interesting, if possible, to connect up this feature with some peculiarity of composition or condition as revealed by the microscope.

And now a point somewhat foreign to the main purpose of this discussion may briefly be referred to. Usu-san falls into line with Skye and Mull in furnishing an instance of peripheral upheaval in an igneous region. Although it is probable enough that the analogy thus afforded is a false one, it is nevertheless one that will have to be borne in mind by students who attempt an interpretation of the curved anticlinal folds so well developed in the case of the two Hebridean examples. Having broached the subject, it is only right to point out that the independence and isolation of the New Mountain of Usu-san is in striking contrast to the systematic grouping of the folds either of Skye or of Mull.

III.—The Green Keuper Basement Beds in Nottinghamshire and Lincolnshire.[1]

By Bernard Smith, M.A., F.G.S.

In the recent memoir on the *Geology of the Country around Ollerton*[2] a description is given of certain 'Green Beds' which in that neighbourhood form the base of the Keuper Waterstones and overlie the Bunter Pebble Beds.

The survey of the Nottinghamshire district being for the time completed, it seems desirable to lay more emphasis upon the occurrence of the Green Beds than has been possible in a sheet memoir.

Their chief importance lies in the fact that they are easily recognizable over a fairly large area and furnish engineers who may be boring for coal or water with a safe guide to the proximity of the surface of the Bunter Pebble Beds. By their aid also we are able to check certain published records in which the dividing line between Keuper and Bunter was perhaps not clearly recognized, and to prepare a contoured map showing the dip of the Bunter surface beneath some part of its overlying cover of younger rocks in Nottinghamshire and Lincolnshire.

In the Ollerton memoir the beds are described as follows:[3] "The greenish clayey basement beds of the Keuper were first noticed by W. T. Aveline, who, in 1861, drew attention to the 'alternations of

[1] With the permission of the Director of H.M. Geological Survey.
[2] Mem. Geol. Surv., 1911.
[3] Ibid., p. 26.

soft blue sandstone and blue clays' at the base of the Waterstones in this part of the county . . . They are 20 to 25 feet thick, and consist of micaceous ripple-marked pale clays, shales and sandy shale, of grey-green, grey-blue, or sometimes reddish tints, with occasional streaks of gritty sand, calcareous nodules in places, and obscure fragments of carbonized organic matter (probably plants)."

The greenish colour of the beds is most marked where they crop out at the surface; in borings the prevailing colour is a bluish-grey or grey. In many cases a thin calcareous conglomeratic sandstone underlies the Green Beds and rests directly upon Bunter sand-rock, but it is impersistent and may be altogether absent. It suggests some slight unconformity between Keuper and Bunter, which is also borne out by field mapping.

Outcrop. At the surface I have seen the beds as far south as Oxton (Sheet 126, N.S.), within 6 miles of Nottingham, and as far north as Retford (Sheet 101, N.S.). In all probability they could be traced further in both directions, for at Nottingham itself (Colwick Road, Sneinton, Sheet 126, N.S.) the lower Waterstones contain grey layers and overlie 3 feet of greenish-yellow flaggy sand-rock, which rests upon a thin conglomerate.[1]

Underground Extension. By means of borings they have been traced underground over a much larger area than their mapable outcrop would suggest, i.e. from Owthorpe (Vale of Belvoir, Sheet 142, N.S.) in the south, to beyond Gainsborough in the north and Lincoln in the east. From the records of some of these borings a table has been constructed (pp. 254–5) to show the persistence of the Green Beds, and the depth at which the Bunter Pebble-Beds occur in each case with respect to Ordnance Datum (see also Figure, p. 256).

In certain cases—marked by an asterisk (p. 254)—my reading of the records differs from the published account, the alteration depending as a rule on the occurrence of the Green Beds, which had been overlooked. The upper limits of the beds are often difficult to determine from the published records, chiefly because no attempt had been made to separate them from the more normal Waterstones above. Had it been possible to examine all the cores, the thicknesses given in the table would doubtless have shown less variability. At Owthorpe, Ruddington, Newark, Tuxford, and Southwell, at least, the figures quoted are probably too small, because layers of red marl sometimes occur with grey and blue layers at a higher level. The cores at Clipston and Rampton, which were personally examined, proved the blue-green facies to be fairly thick. At Markham Moor, about two miles north-west of Tuxford, a boring[2] (at Mr. Mudford's house) proved 30 feet of blue clay and stone resting upon red Bunter Sandstone (— 54 feet O.D.), from which water was obtained as soon as it was struck.

The Rampton (Criminal Lunatic Asylum) boring for water was of great interest because the normal Keuper Waterstones were remarkably like the Keuper Marls. The characteristic red sandstones were so

[1] *Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, p. 37.

[2] Borers' record.

TABLE ILLUSTRATING THE DISTRIBUTION

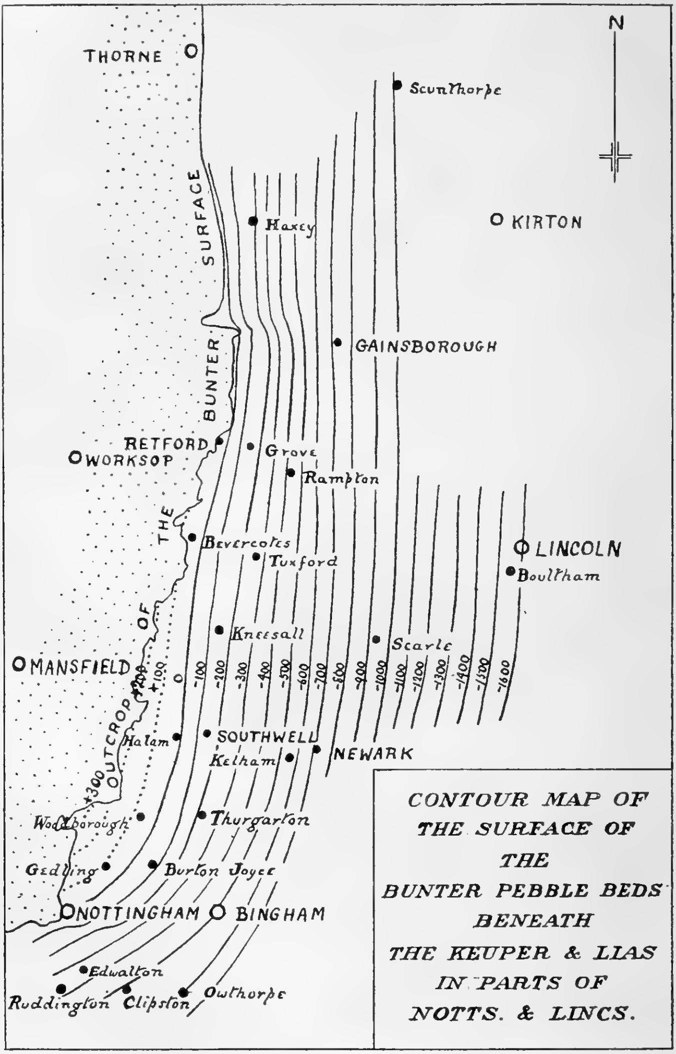
LOCALITY.	1 INCH MAP.	SURFACE LEVEL.	LEVEL OF BUNTER SURFACE.		THICKNESS.			
					WATERSTONES CONGLOMERATE.		GREEN BEDS.	
		Feet.	ft.	in.	ft.	in.	ft.	in.
Owthorpe	142 N.S.	200	−601	6	—		22	6
Clipston	142 ,,	194	−518	0	A few pebbles		37	0
Ruddington	142 ,,	100	−386	8	3	0	21	3
Edwalton*	126 ,,	95	−334	5	0	6	11	3
Gedling (shaft)	126 ,,	185	+108	9	2	10	30	4
Burton Joyce	126 ,,	64	−90	0	2	6	14	0
Thurgarton	126 ,,	57	−210	7	2	8	24	6
Woodborough	126 ,,	116	+80	4	3	3	13	9
Newark	126 ,,	55	−713	0	1	6	25	6
Halam	113 ,,	120	—		2	3	18	0
Southwell	113 ,,	90	−163	10	Hard clay band		12	0
Tuxford	113 ,,	150	−263	0	—		29	0
Bevercotes	113 ,,	95	+57	6	—		18	7
Scarle	114 ,,	35	−923	0	—		12	0
Boultham* (Lincoln)	114 ,,	20	−1542	0	—		27	0
Rampton	101 ,,	110	−427	0	—		28	0
Grove	101 ,,	275	−152	0	—		42	0
Retford (Coal Co.)	101 ,,	50 ±	+8	0	—		30	6
Gainsborough	101 ,,	15 ±	−720	0	—		?	
Haxey* (Idlestop or Southcar)	88 ,,	18	−119	7	—		45	0
Scunthorpe*	89 ,,	25	−1022	8	1	8	86	0
Crosby	89 ,,	14	−932	0	—		?	

* See remarks, on p. 253, on these four localities distinguished by an asterisk.

AND DEVELOPMENT OF THE GREEN BEDS.

Description of 'Green Beds'.	Publication.
Bluish-grey rock.	*Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, p. 107.
Alternations of red and grey sandstones, shales, shaly sandstones, and sandy shales, micaceous and sometimes ripple-marked.	MSS.
Red and grey sandy marl.	*Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, p. 112.
Red and grey sandstone on grey conglomerate with pebbles.	Ibid., p. 100.
Red and grey marly rock.	Ibid., p. 102.
Marl mottled, pale pinkish and greyish, on loose brown sand.	Ibid., p. 99.
Blue marly sandstone, coarse grey sandstone, and red and blue sandy marl.	Ibid., p. 113.
Variegated marl and pebbles and soft sandstone.	Ibid., p. 117.
Blue marl, blue and red marl, sandstone, and cobbles.	Ibid., p. 105.
Blue and greenish clay.	MSS.
Light-blue clay.	*Geology of the Country around Ollerton* (Mem. Geol. Surv.), 1911, p. 78.
Blue sandy marl.	Ibid., p. 78.
Blue loamy sand with mica, red and blue sandy marl, red and shaly sandstone with mica.	Ibid., p. 73.
Specimens at 950 and 958 feet are hard white freestone (water-bearing) and hard grey shale.	*Geology of the Country around Lincoln* (Mem. Geol. Surv.), 1888, p. 194.
Hard grey marl with fine sand bands, grey marl with gypsum.	*Geology in the Field*, pt. iii, 1910, p. 491, and MSS.
Blue marl, blue clay, and red and blue micaceous ripple-marked shales, marls and sandstone.	MSS. and Home Office Record.
Soft and hard blue stone and clay.	MSS.
Red and grey marlstone, and grey pumice (? soft sandstone).	Rep. Brit. Assoc. for 1880, p. 104.
	Geology of the Country around Lincoln (Mem. Geol. Surv.), 1888, p. 97; and Proc. Yorks Geol. and Polytech. Soc., 1891–4, p. 25.
Red and blue marl with gypsum and veins of gypsum and beds of sandstone on 6 feet of red marl.	*Lincolnshire Water Supply* (Mem. Geol. Surv.), 1904, p. 108; and *The Eastern Extension of the Midland Coal-field* (Trans. Federated Institute of Mining Engineers), vol. xii, p. 518, 1896–7.
Red and blue sandy marl, beneath 8 ft. 6 in. red sandstone with grey joints and pieces of marl.	*Lincolnshire Water Supply* (Mem. Geol. Surv.), 1904, pp. 153–4.
Grey sandstones.	MSS.

poorly represented, and beds of marl so well developed, that it was found almost impossible to define where the marls passed into Waterstones. A division was made, however, upon other evidence. The Bunter Sandstone was of the usual type for the district, and contained pebbles as high up as the first 8 or 10 feet.



CONTOUR MAP OF THE SURFACE OF THE BUNTER PEBBLE BEDS BENEATH THE KEUPER & LIAS IN PARTS OF NOTTS. & LINCS.

Details of the Lincoln (Boultham) boring for water were kindly supplied me by Mr. Henry Preston, F.G.S. The interpretation of this section becomes clear if we bear in mind the character of the

Rampton Beds. At Lincoln the Green Beds are well developed, but the lithology of the normal Waterstones is so similar to that of the Keuper Marls that they were thought to be absent. This led to the coarse red sandstone (some beds pebbly), below the Green Beds, being assigned to the Keuper Sandstones—as I think, quite erroneously. The fact that water was struck at 1,561 feet, and that no cores were then obtained until a depth of 1,577 feet was reached, also bears out my interpretation, for it frequently happens that there is a strong rush of Bunter water, which washes out the loose sandy top of the Pebble Beds, when the Green Beds are passed through in borings.

It has been stated[1] that in Lincolnshire the Triassic beds form one series "displaying modifications in texture, colour, and composition, which have no more than a local value; it is in some cases even difficult to decide where a boundary can be drawn between the Marls and the Sandstones, for beds of sandstone occur in the Marls and beds of marl in the Sandstones from top to bottom of the series". At Lincoln, however, the Green Beds represent a distinct horizon whose value has been shown to be of more than local importance, and one which is independent of whether the Waterstones are of the sandy or marly type.

In the Haxey (Southcar or Idlestop) boring for coal it is difficult to fix the base of the Keuper, but it probably occurs (on the evidence of the quantity of blue marl) somewhere near the level given in the table.

Interpreting the Scunthorpe section in the light afforded by those at Rampton and Lincoln, I should place the base of the Waterstones at 1,027 ft. 8 in. from the surface, throwing all the pebbly sandstone (the Waterstones in Notts are almost invariably free from pebbles, except in their basal conglomerate) below it (525 ft. 4 in.), and at present assigned to the Waterstones and Keuper Sandstone, into the Bunter, to which a thickness of only 196 ft. 11 in. is allotted. This classification receives confirmation from the succession determined by a boring near Crosby, situated a very short distance from the Scunthorpe site.

Conclusions. It will thus be seen that although the Green Beds, in the present state of our knowledge, do not form a very trustworthy guide to the underground position of the Bunter surface in the district north of Gainsborough, *they are to be depended upon* in the area which extends from that place as far south as the Vale of Belvoir, and as far east as Lincoln. They should therefore be of peculiar interest to all who may have occasion to probe the Pebble Beds beneath their overlying cover.

The *average* dip of the Bunter Pebble Beds determined from their contoured surface (see Map) is roughly 94 feet per mile, but near the outcrop the dip is slightly higher,[2] viz. 105 feet per mile.

[1] Professor P. F. Kendall, *Final Report of the Royal Commission on Coal Supplies*, pt. ix, p. 33.

[2] *Geology of the Country around Ollerton* (Mem. Geol. Surv.), 1911, p. 25.

IV.—Geological Notes on the Peninsula of Nicoya, Costa Rica.

By James Romanes, M.A., F.G.S.

Contents.

1. Introduction.

During a visit to Costa Rica in the year 1910 I was able to spend about ten days in the comparatively little-known peninsula of Nicoya. The trend of the peninsula is north-west to south-east, and it is separated from the mainland by the Gulf of Nicoya, a shallow arm of the Pacific Ocean, which opens to the sea on the south-east.

The country is almost unmapped, and very little has hitherto been published as regards its geology, although Suess[1] makes special reference to it as a promising field for investigation. Sapper[2] traversed certain parts and records the occurrence of some rock-types, but gives no detailed description whatever. R. T. Hill,[3] in his paper on the Geological History of the Isthmus of Panama, mentions that Sjögren spent some time in Nicoya, and that his results are to be found in an appendix to the paper. No such appendix has, however, been published, and I have been unable to find any account of Nicoya by that author.

I spent some days in the village of Nicoya, which is situated almost in the centre of the peninsula, and then made a journey to the south, getting as far as the Rio de Ora. The area is one of high relief, and range after range of hills is encountered in travelling through it. In certain parts, however, there are broad tracts of level country from which the hills rise abruptly, and reference to this feature will be made in a subsequent part of the present paper. In some respects Nicoya shows close geological affinities with the adjacent portion of the mainland described by the present writer,[4] while in others it affords a striking contrast.

In such accounts as have been previously published there seems to exist a strong impression that older metamorphic rocks contribute largely to the formation of this portion of Costa Rica, but so far as my observations go this is entirely without foundation. It is only fair, however, to point out that this paper is the result of what really amounts to a single traverse from north to south, so that plenty of room remains for the existence of metamorphic rocks; yet throughout all the part with which I am acquainted the geology shows such

[1] *The Face of the Earth*, vol. iv, pt. v, p. 459.

[2] "Ueber Gebirgsbau und Boden des südlichen Mittelamerika": Peterm. Mitth. Erganzungsb., xxiii, No. 151, pp. 26–7, 1906.

[3] "The Geological History of the Isthmus of Panama and portions of Costa Rica": Bull. Mus. Comp. Zool. Harvard, vol. xxviii, p. 222, 1898.

[4] Quart. Journ. Geol. Soc., vol. lxviii, pp. 123–33, 1912.

marked uniformity that I am led to doubt the existence of any rocks differing much from those to be described.

Map of the Peninsula of Nicoya, Costa Rica.

The rocks met with may be divided into three groups as shown below, while in the second column are given the probable equivalents on the mainland.

Nicoya.	Mainland.
3. Nicoyan Series (marine ashes).	Manzanilla Series (? Miocene).
2. Igneous rocks, Teschenites, etc.	Limburgite of Manzanilla area. Monzonites of Cerro Candelaria.
1. Limestones and cherts.	Older limestones of Manzanilla area.

The order of succession given above seems to me the most probable; however, as no actual junctions were found direct evidence is not available, but as will be seen in the following pages there is considerable indirect evidence to support it.

2. Limestones and Cherts.

These are, I think, the oldest rocks exposed in the peninsula, and will probably be found eventually to have a wide distribution. The limestone is well seen about two miles north of the village of Nicoya, where it forms a conspicuous hill along the base of which runs the road to Humo. The rock is fine-grained and almost white, but with numerous joint-faces somewhat stained with iron. Chemical tests show that the limestone contains some magnesia. Little structure is seen under the microscope [9662],[1] as considerable recrystallization has taken place; there are, however, slight traces of organic structure which point to the rock having originally been a foraminiferal limestone. This limestone hill rises sharply from the very level ground which surrounds the village of Nicoya in precisely the same way as the hills of older limestone from the Manzanilla–Avangares peneplain of the mainland. This, coupled with the general similarity in appearance of the deposits, is strong evidence in favour of their belonging to the same series. I believe that many similar limestone hills are to be found, especially to the north in the neighbourhood of Humo; and as in places I have seen the rivers depositing calcareous sinter, limestone is apparently widespread.

The other deposits which I am inclined to include in this series are the Radiolarian cherts, although I quite admit that there is no direct evidence to show that they belong to the same period. These cherts I have only found in place in the upper part of the Rio Marote, i.e. north-west of the Humo road; but there, at least, splendid exposures are to be seen in the river bed over a considerable distance. Unfortunately the junction of the cherts with any other rocks is nowhere exposed. Lower down the stream, but separated by a considerable distance of river gravels, are exposures of the Nicoyan Series, while up stream I was unable to find any rock in place above the cherts. As will be seen from a subsequent part of this paper fragments of these Radiolarian deposits occur plentifully in the Nicoyan Series, which must therefore belong to a later period. The cherts are very hard and compact and vary from red to green in colour, and show much quartz veining on a minute scale. In thin slices [9663, 9664] these rocks are distinctly disappointing; they are evidently rich in Radiolaria, but none of the fine structures are preserved. They show an aggregate of cryptocrystalline silica the Radiolaria being represented by circles of clear microcrystalline quartz. A curious rock-type [9665] occurs plentifully in the Rio Nosara region which may also be of the some nature. It is of a rusty-brown colour with streaks and vesicles of soft iron oxides; the slice of this type certainly suggests affinities with the true cherts.

3. The Igneous Rocks.

Igneous rocks contribute very largely to the formation of Nicoya, and these form an extremely interesting branch of the geology. All the rocks which I was able to collect differ greatly in type from the

[1] The numbers in square brackets refer to slices in the Sedgwick Museum collection.

vast majority of those described from the mainland. Most of them are dolerites which often carry analcime; with them occur coarser and finer grained varieties, but all show a remarkably close genetic relationship; from this area I do not possess one single specimen of an andesite. This indicates that a sudden change has taken place in the comparatively short distance separating the mainland from the part of Nicoya which I visited. The dolerite series must have a wide distribution if we are to judge by the number of boulders brought down by all the rivers.

Time and the difficulties of travel prevented me from making any attempt at mapping even in the roughest way. One point, however, which seemed clear was that round the villages of Nicoya and La Colonia the igneous rocks came on in all cases exactly where the ground rose sharply from the raised peneplain of the Nicoyan Series. I will confine myself here to a description of the various types collected from different localities.

The finest-grained varieties are well exposed in the upper part of the Rio Pila, west of Nicoya village, and they continue westwards over the watershed down to the bottom of the next basin, which is drained by the Rio Quiriman. These rocks are much jointed and veined by calcite, and in the hand-specimen are very fine-grained and non-porphyritic, with a dark, almost black colour. Examined under the microscope [9666, 9667] they are seen to present some affinities with the variolitic basalts, although without a chemical analysis it is not easy to place them definitely. The dominant minerals are felspar and augite; the former is mainly labradorite, but with this occurs some orthoclase. The felspars have crystallized in long acicular crystals which often show plumose and stellate grouping. The augite builds small stout prisms which in the sections give it a granular appearance. Two kinds of interstitial matter are present; a dark-green glass with numerous rods and grains of magnetite, and a colourless isotropic substance of very low refractive index which seems to be analcime. This analcime is present both as interstitial patches and as strings and veins, showing that to a certain extent this mineral must be secondary, though much of it probably represents the final stages of crystallization at a low temperature and with concentration of mineralizing agents. Other zeolitic minerals with low double refraction sometimes replace the analcime, but all the chief characteristics of these finer-grained types recur in rocks with a very wide distribution. In addition to the locality referred to above I have collected similar rocks from the western coast of the peninsula in the Playa Corillo, a bay opening to the Pacific just south of the Rio Buenavista, from the gravels of that river and the Rio de Ora, and also from the watershed above Buenavista, at a height of over 2,000 feet. One or two of these examples [9668, 9669] are distinctly coarser in texture than the type described and appear to be in general holocrystalline and show a transition to the coarser varieties which are true dolerites and will now be described. They are best seen in the hills to the west of La Colonia, especially in the gorge of the Rio Lapa. The typical rock [9670, 9671] is even-textured, dark grey in colour, and consists of a medium-grained aggregate of felspar, augite, analcime, and magnetite. The felspar is mainly labradorite in well-formed lath-shaped crystals. The augite is colourless to pale green, and is markedly granular. In all the slices examined there is a considerable quantity of green uralite derived from the augite. Analcime is generally present, either interstitially or in small secondary veins. In a few instances the occurrence of this mineral is curious, as it forms the central part of the felspar crystal, the boundary between the two being perfectly sharp, although very irregular. These dolerites are, I believe, also abundant, though probably not to the extent of the finer-grained varieties, and simply represent a deeper-seated phase of crystallization, both being derived from almost identical magmas. In a specimen [9672] from the gravel of one of the southern tributaries of the Rio Nosara the texture is somewhat coarser and the augite tends towards the subophitic habit.

One exceptional type [9673] remains to be described: the specimen was collected from a large boulder in the Rio Lapa where the rock probably occurs in place. It is much coarser than any of the foregoing varieties and approximates towards a plutonic habit. The plagioclase felspar is very decomposed, but is distinctly more acid than the usual labradorite, and builds large idiomorphic crystals; along with this is some orthoclase. The chief ferromagnesian mineral is a green augite with slight pleochroism, a variety lying between common augite and ægirine augite; secondary hornblende and magnetite are very abundant. The rock has a distinct resemblance to some of the monzonites of the Cerro Candelaria,[1] and these latter may quite easily represent an outlying part of the Nicoyan alkaline province.

4. The Nicoyan Series.

I have given this name to a group of marine sediments which occupy the lower ground in every part of the peninsula visited by me. These deposits while varying considerably in lithological character preserve, as a series, remarkable uniformity in widely separated localities. They are well exposed in many of the stream sections near the village of Nicoya, and form the flat expanse in which it is situated, but, as previously remarked, wherever the ground rises other rocks take their place. The section along the bed of the Rio Marote may be taken as typical. The deposits are always well bedded, and in the coarser varieties form beds 2 to 3 feet in thickness. They strongly resemble many of the Palæozoic greywackes of Britain. The finer types have the appearance of mudstones or shales. These alternating beds are considerably folded and occasionally dip almost vertically, although gentle anticlines and synclines are more generally developed; here and there some faulting has taken place. The strike of the series is very variable, but E. 30° N. is the normal. The same deposits are exposed further down the Rio Marote at La Colonia, and there again they occupy all the lower ground, but give way to igneous rocks in the surrounding high ground. The beds exposed in the river have a general strike of E. 35° S. with a vertical dip; they are, however, very much affected by minor contortions.

[1] Q.J.G.S., vol. lxviii, pp. 110–12.

To pass now to another part of the peninsula, the same sedimentary series is well exposed along the Pacific coast from the Rio Buenavista to the Rio de Ora. Here the topography is somewhat different as hills and valleys alternate without the broad plains which characterize the land to the north. The sediments extend inland for some distance, but to judge by the river gravels igneous rocks occupy most of the interior.

Buenavista Bay is bounded at either end by a bold rocky headland, and between these stretches a great curving beach of sand. The rock of the eastern headland is very fine-grained, grey in colour, hard and compact, with much calcite veining. The strike is E. 15° S. with a southerly dip of 65°. Similar rocks form the western limit of the bay, but the strike there is N. and S. with a very variable dip to the west. At Samara Point, some distance to the south, the deposits are much coarser in texture and show in hand-specimens numerous rock fragments; the strike is E. 20° S. with a southerly dip of 75°. The farthest south that I reached was the Rio de Ora, and here again this series is seen.

5. Lithology of the Nicoyan Series.

As previously stated these rocks show a very considerable range in texture and appearance; the coarser varieties closely resemble some of the beds of the Manzanilla Series, and are evidently marine volcanic ashes with, however, a considerable admixture of non-volcanic material. An example from the Rio Marote may be taken as typical of these. In the hand-specimen the rock has the general appearance of a coarse, compact, dark sandstone, with numerous slightly rounded rock fragments. Under the microscope this rock [9674] yields much valuable information. It is a slightly calcareous ash or fine breccia similar to that figured by the present writer from the mainland.[1]

Among the rock fragments are Radiolarian cherts identical with those to be found in place a short distance further up the valley. Limestone is present similar to the limestone exposed further to the north and described earlier in this paper. Together with these are fragments of a globigerine mudstone and small pieces of basic igneous rock, not unlike the variolitic basalts of the surrounding hills. The mineral particles consist of angular quartz, much fresh plagioclase, green hornblende and augite, with here and there a little glauconite. The cement is principally calcareous, but the amount present varies greatly in different examples. A specimen [9675] from the river bed at La Colonia is much finer in texture than the above, and contains scattered fragments of analcime. It is therefore, I think, a perfectly safe conclusion to consider the Nicoyan Series as having been laid down while the older limestones, cherts, and igneous rocks were being denuded and probably in many cases being broken up by outbursts of volcanic activity. In these deposits are preserved Rotaline Foraminifera, *Globigerina*, and fragments of the same *Orbitoides* that characterizes the Manzanilla Series, to which I have ascribed a probable Miocene age. The two series are therefore shown to be identical both lithologically and palæontologically.

[1] Q.J.G.S., vol. lxviii, pl. ix, fig. 4, 1912.

Passing southward to the Pacific Coast about Buenavista Bay we have on the one hand types [9676, 9677] distinctly coarser than that described above, while on the other are fine pale marls. The chief mineralogical difference between the former and that described from the Rio Marote are: (1) the almost complete absence of quartz and Radiolarian chert as constituents; (2) the presence of numerous fragments of andesites. The latter is a point of interest, since I noticed a complete absence of these rocks throughout my journey in Nicoya, a very striking difference from the mainland of Costa Rica, where they are by far the most prevalent rock-type. Interstratified with these normal marine ashes are found much finer deposits [9678], which merit description. They present a very fine-grained, compact appearance, and are most commonly of a grey or cream colour, showing a considerable amount of recrystallized calcite. They are very extensively developed in the cliffs at either end of Buenavista Bay. In a thin slice they are at once seen to present close similarity to globigerine ooze. The rock is largely calcareous and treated with dilute acid is reduced to a paste probably composed of volcanic dust. *Globigerina* is abundant, and the shells are infilled either by crystalline calcite or phosphate; the latter is pale brown in thin slices and corresponds to the mode of infilling described by Sir John Murray.[1] A beautiful example of this type [9679] outcrops on the north bank of the Rio de Ora, about $1\frac{1}{2}$ miles from the sea. The rock is somewhat darker than usual, but under the microscope is seen to consist largely of *Globigerina* and presents a striking resemblance to the Chalk Rock of this country. These globigerine mudstones alternate quite abruptly with the volcanic ashes and must represent the sedimentation during periods of quiescence.

6. Coastal Topography.

The coastal topography of Nicoya corresponds exactly with the description of the north-east shore of the Gulf of Nicoya, which I have already published.[2] The inland ridges run out to sea as headlands, and between these are sweeping sandy bays. Buenavista Bay is a pretty example of this. The sand is thrown up into a distinct storm beach which has tended to pond back the river, with the result that much alluvium is being deposited behind the barrier. As on the mainland, large tracts of dark alluvial soil are to be seen, which represent completely silted-up bays, so that while the main coastal outline has been determined by a comparatively recent submergence it has been extensively modified by the deposition of alluvium. Near Humo very large flat tracts of this nature are to be seen.

7. Summary and Conclusions.

The formations met with are divided into three well-marked series:

(*c*) The Nicoyan Series.
(*b*) The igneous rocks.
(*a*) The limestones and cherts.

[1] Report of the scientific results of the exploring voyage of H.M.S. *Challenger*, 1873–6, Deep-sea Deposits, p. 393.
[2] Loc. cit., pp. 131–3.

The first and third of these seem undoubtedly to be represented on the mainland by the older limestones and Manzanilla Series respectively, and thus in the main Nicoya must be regarded as a westward extension of the coastal belt of the mainland, and not as has sometimes been hinted at, as a fragment of some older land mass. The extensive area of flat ground round the villages of Nicoya and La Colonia, which is again seen further to the north, I regard as a prolongation of the raised peneplain which forms the country between Manzanilla and Avangares on the mainland. With regard to the igneous rocks, they undoubtedly belong to an entirely different province from those of the rest of Costa Rica, with the possible exception of the Manzanilla limburgite and the monzonites of the Cerro Candelaria, both of which are more closely related to the Nicoyan series of teschenites than to the pyroxene andesites of the mainland. As regards the age of these alkaline rocks, I am inclined for the present to regard them as intrusive into the older limestones or sediments belonging to the same group, but the relationship of the different rocks is, I suspect, much complicated by faulted junctions.

V.—The Viscosity of Ice.

By R. M. Deeley, M. Inst. C. E., F.G.S.

With a view to showing that distortion under stress may take place in ice when several degrees below the freezing-point, Dr. Main[1] made a number of experiments at St. Moritz in the Engadine during the winter of 1887. Although, as Main says, "The experiments are to be regarded rather as proving the existence of continuous extension under tensile stress than as determining its amount," the records of his tests are sufficiently detailed to admit of the viscosity being calculated.

The tests were all made with the temperature below the freezing-point. He recorded the temperatures at the time extension readings were taken, and in some instances states the range of temperature between observations; but his records do not enable the true mean temperature to be ascertained, for during the nights the temperatures were lower than during the days. On this account the results cannot, except in a somewhat rough manner, be used to ascertain the variation of viscosity with temperature.

These experiments are of particular interest as Kelvin[2] used them in a paper read before the Geological Society of Glasgow in 1888. He says: "Main's experiments gave perfectly definite results though differing considerably with temperature." Adopting a viscosity obtained from Main's experiments, Kelvin comes to certain conclusions with regard to the possible thickness of floating ice fed by snow falling upon it, and also the probable thickness of an ice-sheet on land

[1] Proc. Roy. Soc., vol. xlii, p. 491, 1887.
[2] *Popular Lectures and Addresses*, vol. ii, p. 319.

fed by snow falling evenly over its surface. Recent exploration has shown that Kelvin's conclusions are not very wide of the mark. He does not, however, give any detailed figures, and we are therefore in the dark concerning the figure he took for the viscosity of glacier ice. I have recalculated the mean hourly extensions given by Main, as he had done this somewhat roughly, and in some instances had misplaced the decimal points.

The samples of ice tested were cylindrical, having been formed by freezing water in a metallic mould. In experiment No. 1, Table I, the water was not freed from air, and the test bar contained minute bubbles radiating in horizontal straight lines from the axis of the cylinder. In experiments Nos. 2 and 3 the water was first frozen, then boiled and refrozen in the mould, and only a core of minute bubbles up the centre of the cylinder remained.

The ice was secured in conical holders, and the extension was measured on lengths of from 216 to 244 mm. To prevent rapid changes of temperature the tests were made in two wooden boxes. That the temperatures read are correct is probable, for the thermometer was tested at Kew.

TABLE I.

Experiment No. 1.

A.	B.	C.	D.	E.	F.	G.	H.
Feb. 8 ...	12·5	− 3·7		235·12		2·7	
			− 3·6° C.		2·68		27·83 × 10^{12}
,, 9 ...	12·0	− 3·5		235·75		,,	
			− 3·9		2·33		32·10 ,,
,, 10 ...	12·0	− 4·3		236·31		,,	
			− 3·9		3·04		24·66 ,,
,, 11 ...	12·0	− 3·5		237·04		,,	
			− 2·9		4·08		18·43 ,,
,, 12 ...	12·5	− 2·3		238·15		,,	
			− 2·25		6·50		11·43 ,,
,, 13 ...	11·5	− 2·2		239·65		,,	
			− 3·4		4·41		17·23 ,,
,, 14 ...	12·0	− 4·6		240·73		,,	
			− 5·1		5·30		13·40 ,,
,, 15 ...	11·0	− 5·6		241·95		4·16	
			− 4·9		6·70		15·86 ,,
,, ,, ...	14·0	− 4·2		242·15		,,	
			− 3·65		5·60		21·13 ,,
,, ,, ...	16·5	− 3·1		242·29		,,	
			− 3·1		9·50		12·46 ,,
,, ,, ...	18·5	− 3·1		242·48		,,	
			− 3·8		6·75		14·23 ,,
,, ,, ...	22·5	− 4·5		242·75		,,	
			− 5·25		7·18		16·53 ,,
,, 16 ...	8·25			243·45		4·3	
					4·00		30·70 ,,
,, ,, ...	10·0	Below − 6° C.	Below − 6° C.	243·52		,,	
					4·88		25·17 ,,
,, ,, ...	12·25			243·63		,,	
					3·60		34·83 ,,
,, 17 ...	11			244·45			

Experiment No. 2.

A.	B.	C.	D.	E.	F.	G.	H.
Feb. 19 ...	16·5	−4·2		236·20		2·08	
			−3·85		3·27		$17·96 \times 10^{12}$
,, ,, ...	22·0	−3·5		236·38		,,	
			−3·15		3·00		19·60 ,,
,, 20 ...	10·0	−2·8		236·74		2·1	
			−2·5		2·22		26·80 ,,
,, ,, ...	14·5	−2·2		236·84		,,	
			−4·1		0·42		141·76 ,,
,, 21 ...	12·0			236·93		2·2	
					0·54		117·83 ,,
,, 22 ...	12·0	Below −6° C.	Below −6° C.	237·06		2·3	
					0·34		186·13 ,,
,, 23 ...	11·5			237·14			
			Experiment No. 3.				
,, 27 ...	14·0	−2·8		216·20		1·9	
			−3·25		1·80		27·30 ,,
,, 28 ...	11·5	−3·7		216·59		,,	
			−3·75		1·77		27·83 ,,
Mar. 1 ...	10·0	−3·8		216·99		1·95	
			−2·25		2·22		22·80 ,,
,, ,, ...	19·0	−0·7		217·19		,,	
			−2·35		0·96		52·80 ,,
,, 2 ...	9·5	−4·0		217·33		2·0	
			−2·30		1·06		49·10 ,,
,, ,, ...	17·0	−0·6		217·41			

A, day; B, hour of day; C, temperature at time of observation; D, mean temperature; E, length of test bar in millimetres; F, mean hourly extension in hundredths of a millimetre; G, stress in kilos. per square centimetre; H, viscosity.

Defining the 'coefficient' of viscous traction as

$$\lambda = \frac{f}{\frac{dv}{dx}}$$

when λ is the coefficient, f the force (tractive or tensile) per unit area, and v the velocity at any point x, we have, for cases where the applied force f is so great in comparison with the weight of the bar that the latter may be neglected

$$\lambda = f\frac{v}{x}$$

where v is the rate of extension of a rod of length x.

It has been shown by Trouton that 'the coefficient of viscosity' is equal to one-third of the 'coefficient of viscous traction'.[1]

Applying the above to the first experiment of Dr. Main, given in Table I, we have

$$\begin{aligned} f &= 2·7 \text{ kilos per cm.}^2 \\ &= 2700 \times 980·5 \text{ dyn. per cm.}^2 \\ x &= 235 \text{ mm.} \\ v &= 0·0268 \text{ mm. per hour.} \\ &= 0·0268 \div 60^2 \text{ mm. per sec.} \\ \therefore \lambda &= \frac{2700 \times 980·5 \times 235 \times 60^2}{0·0268} \\ &= 83·5 \times 10^{12} \end{aligned}$$

[1] Proc. Roy. Soc., A, vol. lxxvii.

and the coefficient of viscosity η is one-third of this

$$= 27{\cdot}83 \times 10^{12}.$$

Owing to the unfortunate uncertainty of the mean temperatures at which Main's experiments were made, a perfectly satisfactory comparison cannot be made of the viscosities in Table I.

On the Diagram, however, have been plotted the viscosities calculated from Main's figures. They show, but not very regularly, an increasing viscosity with falling temperature. The curve gives about the mean values of his results; but probably gives too high a viscosity, as his temperatures were taken during the day and may have been lower during the night. From the curve on this diagram the viscosity at 0·0° C. would appear to be about 6×10^{12}.

I have already attempted to ascertain the viscosity of some of the Swiss glaciers from their thickness, slope, and rate of flow.[1] The results obtained are given in Table II.

TABLE II.

Mer de Glace.		Morteratsch.	
At Trilaporte	$29{\cdot}48 \times 10^{12}$	High up	$292{\cdot}2 \times 10^{12}$
At Les Ponts	$27{\cdot}51 \times 10^{12}$	Middle	$143{\cdot}4 \times 10^{12}$
Above Montauvert	$27{\cdot}64 \times 10^{12}$	Near end	$92{\cdot}31 \times 10^{12}$
Below Montauvert	$24{\cdot}16 \times 10^{12}$		

Great Aletsch.	Lower Grindelwald.
$162{\cdot}2 \times 10^{12}$	$3{\cdot}274 \times 10^{12}$

Mr. Connell found that ice crystals sheared readily without fracture in a direction at right angles to the optic axes. From his experiments I calculated that the viscosity in this direction was only 2×10^{10}.[2]

Main's experiments, we have seen, were made with artificially frozen ice. Ice frozen in a metal mould is generally fine-grained, the mass consisting of needles of ice radiating from the centre to the sides. In such cases the optic axes of the crystals would be at right angles to the direction of flow, and the shear which ice can undergo at right angles to the optic axis would not assist the bar to lengthen very appreciably, even though the viscosity of ice in this direction be as low as 2×10^{10}. This arrangement of the individual crystals would tend to give a high value to the viscosity of the ice Main used; but the smallness of the crystal grains or needles would perhaps have a greater tendency to make it low.

Glacier ice, unlike the frozen ice Main used, consists of crystalline granules, varying from the size of a pea to that of a walnut, or even larger. The optic axes are also at all angles, and the ease with which shear takes place at right angles to this axis no doubt tends to lower the viscosity of the mass.

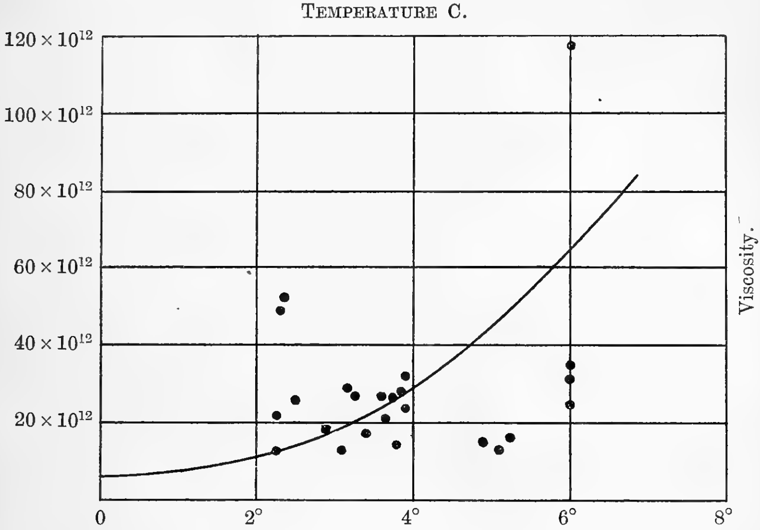
All things considered it would seem that the ice tested by Main had a somewhat lower viscosity than glacier ice. For the viscosity at 0° C. we get from the Diagram 6×10^{12}, whereas the calculations I made from glacier ice led me to take 125×10^{12} as a mean, or about twenty-one times as great as those given by Main's experiments.

[1] Proc. Roy. Soc., A, vol. lxxxi, p. 250, 1908.

[2] Ibid., p. 256.

The probability therefore is that the figure for the viscosity of glacier ice taken by Kelvin was somewhat too low; but, as the volume of ice passed is proportional to the cube of the thickness of the glacier, even if Kelvin used 6×10^{12} for the viscosity, the thickness of the glaciers as calculated by him would only be too small in the proportion of 1 to $\sqrt[3]{21}$ or about 1 to 2·76.

I am indebted to Mr. P. H. Parr for some suggestions with regard to calculations of Main's experimental results.



REVIEWS.

I.—Evolution in the Past. By Henry R. Knipe, F.L.S. 4to, 10 by $7\frac{1}{2}$ inches; pp. xvi, 242, with 56 full-page plates and 4 text-figures. London: Herbert & Daniel, 1912. Price 12*s.* 6*d.* net.

THE above is the title of a new work published this year by the author of *Nebula to Man*, which appeared in 1905. Like its companion this volume is very fully illustrated by fifty-six full-page plates in black and white, fifty being the work of Miss Alice B. Woodward and six by Mr. Ernest Bucknall; but, unlike its predecessor, the present work is written in prose.

There is a small, but increasing, section of the reading public to whom the purely popular or the purely technical treatment of a subject alike give little satisfaction. And on some subjects, among which palæontology might perhaps be included, literature can hardly be found outside these two extremes; therefore a debt of gratitude is certainly owed to Mr. Knipe for so ably supplying a distinctly felt want.

Furthermore, to many people dry bones, even when exhumed after the lapse of many ages, present little or no interest, but Mr. Knipe has given so lucid and realistic a representation of the appearance and life-history of the inhabitants of our globe in earlier times that he may be expected to make numerous converts to the belief that there is no more fascinating study than that of the earth's former inhabitants, including man himself, and one, moreover, in which many secrets remain to be unravelled and many mysteries yet await elucidation.

The book is well and clearly planned, a distinct necessity to ensure success for such a comprehensive undertaking; the author passes in review the successive phases of animal, and more briefly vegetable, life as it has appeared on the earth and is represented by the very earliest known remains until the present-day order of things had been reached. First of all a Chronology of the Earth is given, with a necessary footnote proclaiming that all dates are conjectural though based on the thickness of the various strata, and these will no doubt appeal to many readers who like to reduce all things to terms applicable to the personal life of to-day. This is followed by an introduction giving a simple and brief review of the doctrine of evolution, and a chapter suggesting the probable conditions and manner in which the earliest forms of life appeared on the earth during the 'foundational ages'.

The succeeding sixteen chapters of varying length are each devoted to the description of the inhabitants of the earth during each of the similar number of periods from the Cambrian to that of the present day. The various phases and predominant forms of different epochs are passed in review and provide a clear picture of their several stages and the gradual transformation of the fauna, from the days when invertebrates held unchallenged sway until the time came when Man through his gradually awakening intelligence acquired power for good or evil over all other creatures of land or sea. That man's rise in power has been accompanied by a corresponding decline in the fortunes of mammals of less highly developed brain power is undoubted, and on p. 114 the author draws a pathetic picture of these failing fortunes when he says, "This decline commenced probably in the Pliocene Period, was accelerated in the Pleistocene, and has continued ever since. To-day, brute life, except in a domesticated condition, is at a very low ebb. This long continued downward course is doubtless in part ascribable to climatic changes and disease; but in its later stages it has beyond question been brought about by man."

The numerous full-page plates portraying dominant and peculiar forms, the fossil remains of which have been discovered in deposits of the various periods, form an invaluable complement to the letterpress. These restorations have been prepared with the greatest care and are as reliable as the available material renders possible, and convey a sufficiently accurate impression of the appearance of these extinct species. Five of these plates have already appeared in *Nebula to Man*, but the remaining fifty-one have been specially drawn for this work. Six by Mr. Bucknall show prevailing forms of vegetation which, playing such an important part in the making of scenery, are helpful in giving an impression of the landscapes of different epochs. Miss Woodward's drawings are among the best we have seen of restorations of long extinct forms, for, while faithful to the evidence of structure afforded by the remains discovered, she has exercised an admirable restraint which has enabled her to avoid the tendency, so often seen in the rendering of such subjects, to portray the creatures of the past like nothing more than the grotesques of a fantastic nightmare. At the same time she has succeeded in giving spirited representations of various forms of life ranging from the graceful stone lily to Mousterian man. Where so many show such high merit, it may seem invidious to make a selection for special notice; but among those particularly conveying the feeling of wild life in unrestricted freedom might be cited the plates portraying *Hesperornis* and *Archæopteryx* among the birds, *Mœritherium*, *Machærodus*, *Hipparion*, and the later *Hippidium* of the mammalia; while particular mention may also be made of the plates showing Devonian sharks and Ganoids, Ichthyosaurs preying on Belemnites, and the Jurassic *Diplodocus Carnegiei*.

Considering that so frequent use has to be made of scientific names, the text is singularly free from small clerical errors, though a few may be noticed, such as the two spellings given on opposite pages of the generic name of the 'giraffe-camel' from the Miocene of Colorado.

In his preface Mr. Knipe very generously and rightly acknowledges the valuable assistance received from members of the staff of the British Museum (Natural History) and other specialists, more particularly with reference to the pictured restorations which form such a valuable adjunct to the letterpress. The volume is furnished with a good index and a very useful list of authorities consulted. When preparing this work for a second edition it might be suggested that a few sketch-maps indicating the extent of the earth's land surfaces during different periods might still further add to its completeness.

On nearly every page are marginal headings, if one may be permitted the use of such a term, which will be found of great assistance when employing this as a work of reference.

We sincerely hope that the volume under review will eventually have to be referred to as one of Mr. Knipe's 'earlier works', and it is in anticipation of its successors that it may be well to suggest to the author that, while technical language is necessarily to be avoided, a tendency to err in the opposite extreme is to be deprecated on the ground that, while more intelligible, it is perhaps even more aggravating to the reader. As an example taken at random, we may mention his reference to 'Trunky life' in India in early Pliocene times; the 'elephants' in the margin is illuminating; nevertheless one is left with the impression that this is hardly the expression best suited for the occasion, and that one would be similarly affected if in reading a History of England, for instance, the author were to refer to Alfred the Great as 'Alf'.

In conclusion, it may be said that this handsome volume is well got up and printed on good paper, which is satisfactory to note when the many illustrations are necessarily reproduced on a heavier make with a smooth surface; and it may be safely recommended to those interested in palæontology and to whom scattered scientific papers may not be available, as a thoroughly up-to-date and agreeable outline of the subject.

II.—Prehistoric Man. By W. L. H. Duckworth, M.A., M.D., Sc.D., University Lecturer in Physical Anthropology, Cambridge. 8vo; pp. 150. Cambridge: University Press, 1912. Price 1*s.* net.

THE Antiquity of Man was written by Sir Charles Lyell just half a century ago, and marked an epoch in the study of the early human race; it gave an impetus to and an interest in that subject which have only increased as time has run on, and were never greater than at the present moment. During much of that time the interest centred chiefly around the ancient stone implements which from their indestructible nature have been found in surprising numbers, not only in this country and on the continent of Europe, but in every quarter of the world. The remains of man himself from the deposits where his handiwork has been so abundant have been comparatively few. Indeed, considering the enormous number of animals' bones obtained from Pleistocene deposits, it is remarkable that those of man should have been so seldom recorded. However, during the last ten or fifteen years some most interesting discoveries have been made, and it is chiefly these which are dealt with in the present volume. It is very fitting that the jubilee of *The Antiquity of Man* should be marked by the publication of this admirable little book by a master of anthropology, which will certainly serve many students as an introduction to the study of 'prehistoric Man'.

Limited space (150 pages) has not permitted the author to do more than give a general view of the subject, but he has contrived to condense in that space a large amount of information in a somewhat novel and interesting form. It is reassuring at the outset to find that Dr. Duckworth refuses to give "dates in years to the several divisions of time now recognized", and our faith in his judgment in other parts of his book is thereby strengthened.

In the first place the author reviews the various well-authenticated discoveries of human remains in Pleistocene and earlier deposits during the last fifteen years. And we may here say how much we should have liked to have had a somewhat full account of the peculiarities of the Spy skeletons which have served as a foundation for the characters of the Neanderthal race.

A novel method of comparing these remains is adopted. Disregarding, for the time, the horizons from which the skeletons have been obtained, these have been grouped according to their greater or less resemblance to the bones of modern men; and this emphasizes some peculiar points. In the *first* group are included *Pithecanthropus* and the Heidelberg jaw, these forming two divisions of a group far removed from modern man, and at the same time occurring in far-off *pre*-Palæolithic deposits. A *second* group includes Palæolithic and modern men; but these are put in two divisions—(*A*) The Neanderthal (or La Chapelle) race; and

(*B*) Modern men and certain fossil remains which can hardly be separated from them, such as the Engis skull and the Galley Hill skeleton. If it be accepted that the Galley Hill man is thus closely allied to modern men, then, as the Galley Hill skeleton was found in deposits much older than those yielding the remains of the Neanderthal race, we have to account for the more modern type being in the older deposit.

In subsequent chapters are considered the relation of these fossil human remains to the deposits in which they are found and to the mammalia and flint implements with which they are associated. Then follows an account of the attempts which have been made to divide the Pleistocene deposits and of the Glacial and Interglacial arrangements which have been suggested. Finally, Dr. Duckworth traces the possible lines of the evolution of man.

Throughout the book the author has striven to give a general account of the various phases of the study of prehistoric Man rather than to express definite opinions on any of the thorny problems with which the subject is beset. There is a capital bibliography, however, which will enable the student to consult the original authorities for himself and, it may be, draw his own definite conclusions.

E. T. N.

III.—Geology of the Federated Malay States.—We have received from Mr. J. B. Scrivenor, Geologist to the Government of these States, an account of *The Geology and Mining Industries of Ulu Pahang, with a sketch map showing the geological structure of the country* (1911).[1] The geological map is the first, so far as we know, that has been published, of any part of the States. It is on the scale of 8 miles to 1 inch, is clearly printed in colours, and the topography has mostly been surveyed by Mr. Scrivenor. The formations include—(1) The *Raub Series*, limestones and shales with fossils of Carboniferous and Permian. (2) The *Chert Series*, consisting of black and coloured cherts with abundant Radiolaria, jasper, and siliceous shale, also with a few Radiolaria: in one locality there was a thin seam of Radiolarian chert between a flow of lava and an underlying bed of ash; fragments of chert occurred in the lava, but the relations between the Chert Series and other formations have not been clearly determined. (3) The *Gondwana rocks*, comprising conglomerate, quartzite, sandstone, grit, shale, and clay-slate: fossils from the sandstones include several species of *Myophoria* and *Chlamys valoniensis* (characteristic of Rhætic), so that the strata are referred by Mr. R. B. Newton to the uppermost Trias; a species of *Semionotus* has also been identified by Dr. A. Smith Woodward; pebbles of chert resembling the rock of the Chert Series occur abundantly, and suggest unconformity between the Gondwana and Chert Series. (4) The *Pahang Volcanic Series*, consisting of lavas and ashes and some deep-seated rocks, a group that appears to be associated more or less with all the three preceding groups, and to be older than (5) the *Granite* of the Main Range.

[1] On sale at the Malay States Information Agency, 88 Cannon Street, E.C. Price 3*s*. 6*d*.

The author describes some of the igneous rocks, granophyre, andesite, dacite, dolerite, etc. He comments on the association of Radiolarian chert and lava, and on the views expressed on the subject by Mr. H. Dewey & Dr. J. S. Flett.[1] The newest rocks, apart from Alluvium, are small dykes of dolerite which cut the granite, and are almost certainly of Tertiary age.

With regard to the mining, gold has been obtained from alluvial deposits and from weathered rocks in sufficient quantity to repay a Malay, but not a white miner "unless he chose to live like a Malay". Two mines are still being worked in lodes in the Raub Series. The greater part of Ulu Pahang produces no tin-ore, and the author fears it never will be obtained in any part in large quantities.

Mr. Scrivenor has also published *Notes on prospecting for Tin-ore in the Federated Malay States* (Kuala Lumpur, 1911).

IV.—Geological Survey of New Zealand.—Bulletin No. 13 (New Series), issued by the Department of Mines, consists of a memoir on *The Geology of the Greymouth Subdivision, North Westland*, by Mr. Percy G. Morgan (Wellington, 1911, pp. 159). This work is illustrated by four detailed geological maps and three sections, together with special maps of the Kotuku Oilfield and Greymouth Coal-field, and sundry pictorial views and text-illustrations. The district lies on the western side of the southern island, and contains the following geological formations: *Palæozoic*, Greenland Series, composed of argillites and grauwackes that may be of any age from Ordovician to Carboniferous; *Eocene*, Coal-measures; *Miocene*, Greymouth Series, mudstones, sandstones, limestones, and conglomerates; *Pliocene*, sandstones, lignite, and gravels; *Pleistocene*, glacial, fluviatile, and marine deposits; and *Recent*, fluviatile and marine gravels and sands. Igneous rocks include granite of an age newer than the Greenland Series and pre-Tertiary, and basic dykes that may be slightly younger than the granite.

The Greenland Series has yielded some metalliferous quartz-veins with gold and ores of antimony, but there has been little lode-mining: gold has been obtained in some abundance mainly in the Recent alluvial deposits, to some extent in Pleistocene deposits, and in small quantities in Pliocene and earlier Tertiary accumulations.

While mining is the chief industry, that of coal-mining is by far the most important; the output for 1910 was 466,661 tons, and the total amount of coal raised since 1890 is estimated at nearly six million tons. Considerable increase is anticipated in the output of coal. It is stated that favourable conditions for the occurrence of petroleum in quantity seem to exist, but until deeper trial-holes have been put down the matter cannot be settled. Notes are given of other mineral products, of building-stones, materials for brick-making, cement, etc. From an agricultural point of view there is little arable land, but much grass land suitable for cattle-grazing, good timber land, and some ground adapted for fruit-farming.

[1] Geol. Mag., 1911, pp. 202, 241.

V.—Geological Survey of the Transvaal.—In the volume of Annual Reports for 1910, part iv (1911), the Director, Mr. H. Kynaston, gives a general account of the field-work, with some important particulars relating to building-stones, illustrated by twelve pictorial views of quarries. Mr. E. T. Mellor contributes a Report on "The Geology of a portion of the Central Witwatersrand", with a map showing the structure of the area; another Report is on "The Geology of the Steelpoort River Valley, including the country round Roos Senekal and Dullstroom", by Mr. A. L. Hall, illustrated by views, sections, and a coloured geological map; a third Report is on "The Geology of the Rustenburg and Zeerust Bushveld south of the Dwarsberg", by Mr. W. A. Humphrey, and a fourth Report, by the same geologist, is on "The Transvaal System west of the Klip River Valley", both illustrated by coloured geological maps.

VI.—Yorkshire Geological Society.

SOME very interesting papers are contained in part iii (vol. xvii, n.s., 1911) of the Proceedings, issued in January last. The Presidential Address is printed herein, and in this Professor P. F. Kendall deals with the Progress of Geology, with special reference to Yorkshire, during the fifty-two years in which the Marquis of Ripon (his predecessor) was President of the Society. An important paper follows on "The Lower Oolites of Yorkshire", by Mr. L. Richardson. The succession of beds at Blea Wyke, Ravenscar, is given; but the *aalensis* and *moorei* beds (between which the division line between the Lias and Oolites is generally drawn) are absent at this locality. The Dogger is found to rest upon a deeply-eroded surface of the Lias, and hence the division line between the Lias and Oolites is usually sharply defined. The subdivisions of the Oolites are considered in detail, and the paper is illustrated by three fine photographs. Three appendices follow, two by Mr. S. S. Buckman on the Ammonites (one being a comparison of the Upper Toarcian Beds in Yorkshire and in the Cotteswolds), and the third by Mr. Talbot Paris on the Echinoids.

A beautifully illustrated paper is contributed by Mr. G. W. Lamplugh "On the Shelly Moraine of the Sefström Glacier and other Spitzbergen phenomena illustrative of British glacial conditions", an abstract of which was delivered at the Sheffield Meeting of the British Association, 1910 (Section C). The paper contains a note by Dr. A. Strahan and a list of shells by Professor Gerard de Geer.

Some interesting results of the careful collection and study of Chalk Belemnites are presented by Mr. J. W. Stather. A complete transition can be traced from *Actinocamax westphalicus* through *A. granulatus* to *A. quadratus*, and the forms show a deepening of the alveolar cavity as they are collected from successively higher Chalk. A convincing diagram accompanies the text, and this shows the actual depths of the alveolar cavities of a series of specimens collected from the Upper Chalk of Yorkshire, the exact measurements through 650 feet of Chalk being given with each specimen. These results were first obtained by M. de Grossouvre, and were confirmed by Dr. Rowe's researches in the South of England. In Yorkshire, however, Mr. Stather is the first to collect the complete series.

Dr. Albert Wilmore contributes a "Note on the Zones of the Carboniferous Limestone South of the Craven Fault", and Dr. Arthur Vaughan describes and figures *Clisiophyllum ingletonense*, n.sp., a form "with strong convergence towards *Carcinophyllum*, particularly in the young stages", and occurring in the basement beds (C_2–S_1) of Ingleton.

VII.—Liverpool Geological Society.—The last part of the Proceedings (vol. xi, pt. ii, session the fifty-second, 1910–11) contains a great deal about Triassic geology. Mr. W. Hewitt in his Presidential Address, gives a comprehensive account of the present state of our knowledge of the physical conditions under which the local Triassic rocks were formed. The various theories are discussed and the more important papers referred to, but, as Mr. Hewitt observes, the problem is still an open one. Footprints in the Trias form the subject of papers by Mr. H. C. Beasley and Mr. F. T. Maidwell. Mr. Beasley deals with the group of footprints found at Storeton in 1910, and from the new examples is able to write a fresh description of the 'G' (Chelonoid) forms. These Storeton 'G' prints are not webbed, but recently an undoubted example of webbing has been discovered among the Rhynchosauroid prints at Runcorn. Mr. F. T. Maidwell, in his "Notes on the Footprints from the Keuper of Runcorn Hill", describes several of the 'D' prints under the name *Rhynchosauroides*, and founds the new species *R. membranipes*. Some interesting observations on webbed prints and the significance of their occurrence in these rocks, are included in Mr. Maidwell's paper.

The finer materials of Triassic rocks have been examined by Messrs. C. B. Travis & W. H. Greenwood, who give their detailed results in a paper on the mineralogical and chemical constitution of the Triassic rocks at Wirral. These results are compared with those obtained by workers in other areas, and the conclusions are of some interest. The condition of the quartz tends to show that the bulk of the material of the Wirral Trias was derived from granitoid rocks, and a smaller proportion from sedimentary and volcanic rocks. The two varieties of tourmaline, brown and blue, are considered to come from different sources. On the whole, the authors think that the Wirral Trias cannot have been derived from the same source as that of the deposits of the Trias in South-West England and the Midlands.

The list of papers on the geology of the country around Liverpool which was started by the late Mr. G. H. Morton is continued in this part of the Proceedings to the year 1909, by Mr. W. Hewitt.

VIII.—Proceedings of the Cheltenham Natural Science Society for the Session 1910–11. n.s., vol. i, pt. v, November, 1911. Cheltenham: Norman, Sawyer & Co., Ltd. Price 1*s*.

THE useful account of "Brickearths, Pottery, and Brickmaking in Gloucestershire", by L. Richardson and R. J. Webb, concludes in this part of the Proceedings with details of the various tile-and brick-clays in the Coal-measures and in the Old Red Sandstone. The famous Cattybrook bricks are made from the Coal-measure clays of this county; and six localities are still worked, while eight are now disused. The three localities from which the Old Red Sandstone supplied bricks are now disused.

This part contains, besides the Presidential Address (by Dr. E. T. Wilson) on "Our Inheritance", a short paper on "Stone Circles on the Blackhedge Estate", by Mr. L. Richardson, and a note by Dr. A. Smith Woodward on "*Euthynotus*: a Fossil Fish from the Upper Lias of Dumbleton, Glos."

IX.—Micropetrology for Beginners: an Introduction to the use of the Microscope in the examination of thin sections of Igneous Rocks. By J. E. Wynfield Rhodes, B.Sc. 8vo; pp. xv, 126, with 1 plate and 26 text-illustrations. London: Longmans, Green & Co., 1912. Price 2*s*. 6*d*. net.

THIS little book, introduced to the public in a preface by Mr. C. H. Sidebotham, F.G.S., will prove a useful primer for the student, and will no doubt be an aid to those going up for examination in petrology. The methods of preparing thin slices of rock and of identifying the minerals under the microscope, the composition of the principal rock-forming minerals and of the igneous rocks, including such forms as Laurvigite, Foyaite, Ditroite, Hyperite, Markfieldite, and Teschenite, are treated systematically and concisely. Finally, there is a glossarial index.

X.—The Voyage of the *Discovery*. By Captain Robert F. Scott, C.V.O., R.N. Re-issue, 2 vols. 8vo; pp. xiv, ix, 410, 387, with 12 plates and 2 maps. London: Smith, Elder & Co., 1912. Price 3*s*. 6*d*. each vol.

THIS work was originally published in two large octavo volumes in 1905. It has now been re-issued in smaller size and at a price which will be welcome to many geologists and students in different branches of science, as well as to a wide circle of other readers interested in this fascinating record of arduous and successful exploration. The text has been reproduced intact, with the summary of the geological observations by Mr. H. T. Ferrar, and the account of the whales, seals, and birds by Mr. E. A. Wilson. To the student of glacial phenomena the whole narrative is full of instruction on ice and ice-action, and the only regret felt will be in the fact that but few of the original illustrations have been reproduced.

XI.—Brief Notices.

1. Mineralogical Notes.—Under the title "Mineralogical Notes, Series 1", the United States Geological Survey has published Bulletin 490 (Washington, 1911), by Dr. Waldemar T. Schaller. This is a continuation of Bulletin 262 (1905), and contains the results of further research carried on by the author in the chemical laboratory of the Survey. Some of the papers were originally written and published in conjunction with members of the Survey; acknowledgment has been made to these, and some papers have been re-arranged. Among the minerals considered chemically, hulsite, paigeite, jamesonite,

and warrenite may be mentioned, and a few pages are devoted to the composition of molybdic ochre. Some new forms of calcite crystals are also described.

2. Fossil Beaver from California.—Publication 17 of the University of California (Bulletin of the Department of Geology) contains the description and figures of a tooth m. 2 of *Castor californicus*, n.sp., by Dr. Louise Kellogg. The specimen was found at the northern end of the Kettleman Hills, Fresco County, and is of Middle Etchegoin (late Miocene or early Pliocene) age, being therefore the earliest known true beaver from America. It is very similar in pattern to the teeth of various recent species of *Castor* found on the Pacific Coast, and is compared with *C. neglectus*, Schlosser.

3. Geology and Folk-lore. — An interesting essay entitled "'Snakestones' and Stone Thunderbolts as subjects for systematic investigation" has been communicated by Mr. Walter W. Skeat (*Folk-lore*, xxiii, p. 45, March, 1912). He has given many records of fossils used as charms or as medicinal cures, or connected with forms of worship. Thus, in India both celts and ammonites are connected with the worship of Vishnu.[1]

4. British Late-Glacial and Post-Glacial Deposits.—An essay by Mr. G. W. Lamplugh on this subject was brought before the International Geological Congress at Stockholm in 1910 (reprinted from the *Postglaziale Klimaveränderungen*). After expressing his conclusions "that there is no clear evidence for the supposed separate glaciations and warm inter-Glacial epochs, but on the other hand there is strong evidence that the main ice-sheets persisted throughout the Glacial period, and only their margins oscillated widely", he proceeds to discuss the field-evidence, which leads him to believe that the post-Glacial deposits were accumulated during progressive amelioration of climate.

REPORTS AND PROCEEDINGS.

Geological Society of London.

March 27, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read :—

1. "The Glaciation of the Black Combe District (Cumberland)." By Bernard Smith, M.A., F.G.S.

After a brief discussion of previous work and literature, a short sketch is given of the geological structure of the district.

With the exception of the western coastal plain the main topographical features are pre-Glacial, but they have been either subdued or accentuated by glaciation. The chief pre-Glacial drainage-lines determined those of the present day.

Evidence is given to show that, during the flood-tide of glaciation, the whole district was swamped beneath an ice-sheet formed by the

[1] See also Dr. H. Woodward, "On Fossils applied as Charms or Ornaments": Geol. Mag., 1893, p. 246.

confluence of Lake District and Irish Sea ice, the summit of Black Combe (1,969 feet) being overridden by ice which was comparatively clean.

The Lake District ice travelled from the Broughton Valley, the Duddon Valley and high ground to the west, and from Eskdale. Near the coastline the overmastering pressure of the Irish Sea glacier diverted the seaward flow of the Lake District ice to the south or south-east.

The deposits of the Lake District ice are briefly described, and a more detailed description is given of the deposits of the Irish Sea ice which are exposed in the sea-cliffs of the coastal plain. The distribution of Scottish boulders is also discussed.

In the Lower Boulder-clay of the westward mountain slopes (the ground-moraine of combined Lake District and Irish Sea ice) there is evidence both of the interweaving of drifts of distant and strictly local origin, and of a certain amount of movement of ice inland.

Phenomena which occurred during the withdrawal of the ice are next described under the following heads:—

(1) *Moraines and trails of boulders.*

(2) *Marginal channels and associated sands and gravels.*—The trend of these channels is, in the best examples, parallel to the coast and nearly at right angles to the present drainage-lines. In some cases the channels were carriers of the ordinary marginal drainage of the ice-sheet, in other cases they were cut by overflow waters from impounded lakelets. Before the cutting of the channels between Eskdale and Bootle the ice overrode a series of sands and gravels formed, chiefly as a marginal outwash-fan, at a slightly earlier date.

(3) *Sand and gravel of the plain.*—These deposits are considered to have been accumulated after the formation of the channels near Bootle, the material being in the main deposited in embayments of the margin of the Irish Sea ice.

(4) *The Whicham Valley and Duddon Estuary Lakes.*—Sand and gravel was also accumulated at the extremities of ice-lobes which were thrust into the mouths of valleys, so that the normal drainage of these valleys was obstructed. The ice-dammed Whicham Valley Lake is described in detail; it drained at first into the Duddon Estuary by the Gill Scar channel, but afterwards through the obstructing barrier—reversing the flow of water.

The Upper Boulder-clay is then briefly discussed, and some account is given of late corrie glaciation.

In conclusion, certain hanging valleys are shown to be due to the over-steepening of hill-slopes, or over-deepening of main valleys during the maximum glaciation.

2. "The Older Palæozoic Succession of the Duddon Estuary." By John Frederick Norman Green, B.A., F.G.S.

The Lower Palæozoic geology of the estuary of the Duddon, which separates Cumberland and Lancashire, has been little studied, but is of especial interest, because the (?) Skiddaw Slate, Volcanic Series, and Coniston Limestone Series are in proximity along an outcrop of several miles, and the alteration is generally less than in other parts of the Lake District. The following succession is described in descending order:—

	Thickness in feet.	
Limestones (Sleddale Group)	100	
Stile End Beds	40	
(unconformity)		
Upper Tuffs	40	Volcanic group, 650 feet.
Rhyolites	60	
Harrath Tuffs	100	
Middle Tuffs	300	
Dog Crag Tuffs	50	
Mottled shale	100	
Blue shale or (?) Skiddaw Slate—no base seen.		

The blue shale and mottled shale are described; and it is shown that the latter is identical with the former, except for the addition of lapilli of andesite-glass and slate. Tuff-free bands, indistinguishable from blue shale, are intercalated. Conformity is also proved by mapping and by sections exposing the junction.

The Dog Crag type is of the same material as the mottled shale, but with little muddy matrix, and passes up into the bedded Middle Tuffs, composed of fine-grained debris; these in turn pass up into the Harrath type, marked by fragments of variolite, and, in the upper part, felsite. The rhyolites are considered to be substantially contemporaneous. The thin andesitic Upper Tuffs are only seen in the neighbourhood of Millom.

The pyroxene-andesites of the district are briefly described. They vary from acid forms with oligoclase in the ground-mass and felspar-phenocrysts, to forms with an andesine-augite matrix and augite-phenocrysts. They occur sporadically in any horizon from the Skiddaw Slate to the rhyolites, and in many cases are certainly intrusive. The sills metamorphose the Middle Tuffs near their margins into 'hälleflintas'.

It is next shown that the whole succession has been thrown into folds with axes trending north-east and south-west, and now lies in folded sheets with a low dip, though the bedding dips are high. This folding having been determined, it is possible to decide the relationship of the Coniston Limestone Series to the underlying beds. Near Millom the Upper Tuffs and Stile End Beds are developed. The latter are composed of detrital igneous matter. At Waterblean the Stile End Beds disappear. At Graystone House, near Duddon Bridge, where an important exposure of fossiliferous limestone was discovered among the volcanic rocks by Sedgwick, the Upper Tuffs are also absent. On the east side of the estuary mapping shows the limestone lying upon the Dog Crag type, the mottled shale, and the blue shale or andesite. The conclusion that an unconformity exists was confirmed by a trench cutting Coniston Limestone resting upon undisturbed intrusive augite-andesite.

The existence of a powerful strike-fault is proved by the position of the Graystone House Limestone and by repetition of the upper part of the volcanic group.

April 17, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The President announced that the Council had awarded the Proceeds of the Daniel-Pidgeon Fund for the present year to Otway H. Little, M.A., Royal College of Science for Ireland, who proposes to investigate the chemical and mineral changes which have taken place in the metamorphic limestone of Connemara.

The following communications were read :—

1. "The Pre-Cambrian and Cambrian Rocks of Brawdy, Hayscastle, and Brimaston (Pembrokeshire)." By Herbert Henry Thomas, M.A., B.Sc., Sec. G.S., and Professor Owen Thomas Jones, M.A., D.Sc., F.G.S.

The district dealt with in this paper lies about eight or ten miles to the east of St. Davids, and consists of pre-Cambrian plutonic and volcanic rocks surrounded by, and intimately associated with, sedimentary rocks of the Cambrian System.

The pre-Cambrian igneous and pyroclastic rocks are brought to the surface along an anticlinal axis which ranges in an east-north-easterly and west-south-westerly direction, that is to say, approximately parallel to the ancient ridge of St. Davids. They are distributed over an area measuring about nine miles in length by two miles in greatest breadth.

The pre-Cambrian rocks are divisible into two classes, an older volcanic series and a newer plutonic and hypabyssal series, for which Hicks's names of Dimetian and Pebidian are respectively retained.

The authors have not attempted any detailed subdivision of the Pebidian over the whole area, but it is clear that several stages are represented. The lower exposed portion is generally andesitic in character, the upper being rhyolitic and keratophyric.

The Dimetian comprises granite, quartz-porphyry, and diorite, which are intruded into the Pebidian, and present a common feature in the abundance of soda-felspar. Petrographical descriptions of the various pre-Cambrian rock-types are given.

The Cambrian has been divided into two main groups—the Welsh Hook Group below and the Ford Beds above. The Welsh Hook Group compares bed for bed with the Caerfai and Lower Solva Series of Hicks, and, like similar beds at St. Davids, consists of basal conglomerate, green sandstones, red shales, and purple sandstones.

The position of the Ford Beds, which are mostly shales, is not so certain; but the evidence is in favour of their belonging to the Upper Solva stage, and their having transgressed lower members of the Solva Series.

The basal bed of the Cambrian apparently rests upon rocks of different ages in different parts of the district; and this fact, taken into consideration with other evidence, indicates that the Cambrian reposes unconformably on a complex series of tuffs and lavas and of plutonic rocks intruded into these volcanic rocks.

The structure of the district is that of a horst, faulted on all sides and surrounded by much younger beds. The main fractures follow an east-north-easterly to west-south-westerly direction, but frequently branch and run together, thus enclosing lenticular masses.

Much of the faulting is of pre-Carboniferous age, but that it continued into Carboniferous times is shown by the manner in which the Carboniferous rocks of the district have been affected.

2. "The Geological Structure of Central Wales and the adjoining region." By Professor Owen Thomas Jones, M.A., D.Sc., F.G.S.

This paper deals with the structure on a large scale of an area of about 1,800 square miles, comprising the western portion of Wales between the River Dovey and South Pembrokeshire. In an historical introduction the work of earlier observers, notably Sedgwick, Ramsay, and Walter Keeping, is referred to.

The paper is accompanied by a map whereon is indicated the distribution of certain rock-groups: this map is based partly on personal observations and partly on information gathered from various publications.

On the map the structure of the area is easily perceived. There are two principal anticlinal axes which follow in the main the valleys of the Teifi and the Towy, and are named after these rivers; between them is an important syncline (the Central Wales Syncline) which coincides nearly with the principal watershed of Central Wales.

Both the anticlines can be traced towards Pembrokeshire, where they appear as important structures; but they cannot be distinguished beyond the northern boundary of the area. The syncline, on the other hand, becomes more important in a northerly direction, but is lost towards the south-west. These structures have a southerly pitch at the northern end of the district, and a pitch in the opposite direction at the southern end. The variation in the pitch accounts for the form of the outcrops.

The peculiar correspondence between the evenly curved courses of these structures and the form of the coastline of Cardigan Bay, as also the relation of the structures to the other physical features, are discussed.

May 1, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The President referred to the loss which the Society had just sustained in the decease of Mr. Joseph Dickinson, at the age of 93. Mr. Dickinson had been a Fellow of the Society for no less than seventy years, having been elected in 1842, and he had retained undiminished to the last his keen and vigorous interest in geological and mining matters.

The following communications were read:—

1. "On the Geology of Mynydd Gader, Dolgelly; with an Account of the Petrology of the Area between Dolgelly and Cader Idris." By Philip Lake, M.A., F.G.S., and Professor Sidney Hugh Reynolds, M.A., F.G.S.

Mynydd Gader lies immediately south of the area described by the authors in a previous paper (Q.J.G.S., vol. lii, pp. 511–21, 1896). The Tremadoc Beds are here succeeded by a group of rocks which are, for the most part, of volcanic origin. These may be divided into a Rhyolitic Series below and an Ashy Series above. The Rhyolitic Series is formed chiefly of lava-flows; the Ashy Series consists mainly of volcanic ashes and slates, the ashes predominating below and the slates above. *Didymograptus bifidus* occurs near the base of the Ashy Series, *D. Murchisoni* in the upper part.

There is not sufficient evidence to show whether the Rhyolitic Series is conformable or unconformable with the Tremadoc Beds; but, since it lies between the *Dictyonema* Zone and the *Didymograptus bifidus* Zone, it belongs presumably either to the Lower or to the Middle Arenig. The Ashy Series extends from the Upper Arenig to the Llandeilo.

There are many intrusive masses of igneous rock, the largest being that which forms the greater part of Mynydd Gader itself. This intrusion is L-shaped in section, consisting of a horizontal limb which cuts across the beds, and of a descending limb which lies approximately in the bedding.

The petrology of the igneous rocks, not only of Mynydd Gader, but also of the area described in the previous paper, is dealt with.

The intrusive rocks are mostly dolerites, consisting chiefly of augite and plagioclase (labradorite-andesine), without olivine or rhombic pyroxenes. Epidote is very abundant as an alteration product. Contemporaneous veins are met with at one locality. Small intrusions of eurite occur just beyond the limits of the map.

The rhyolites are sometimes compact, sometimes banded, and sometimes nodular. Analyses of two specimens, the one compact and the other nodular, show that the percentage of soda is high.

The tuffs or ashes vary considerably in character. Some consist of a fine matrix with numerous scattered angular fragments of all sizes up to 18 inches; the fragments are mostly rhyolitic, but pieces of slate and grit also occur. In others the fragments are smaller, and some are so finely laminated that on freshly broken surfaces the texture appears perfectly uniform, but on weathered surfaces the lamination is often quite distinct.

Andesitic lavas occur at two horizons, in the Upper *Lingula* Flags and in the Llandeilo Series. The latter are often highly amygdaloidal.

The Rhyolitic Series appears to be older than the main mass of volcanic rocks in the Arenig area, but it may be contemporaneous with the *Calymene* Ashes of that district. It is probably of approximately the same age as the volcanic series of Skomer Island, and the fact that in both places the rhyolitic rocks are soda-rhyolites is of considerable interest.

2. "Insect-Remains from the Midland and South-Eastern Coal-fields." By Herbert Bolton, F.R.S.E., F.G.S., Director of the Bristol Museum.

The writer describes a series of three insect-wings obtained by Dr. L. Moysey, F.G.S., from the Shipley Clay-pit near Ilkeston (Derbyshire), and a blattoid wing and three fragments from the borings of the Kent Coal Concessions Company, Ltd., in East Kent.

The first series of insect-wings occur in greyish-brown ironstone nodules, which lie in bands in a yellow clay about 30 or 40 feet below the Top Hard Coal.

The East Kent insect-remains occur in core shales, the horizon of which is not yet determined.

The wings obtained by Dr. Moysey are not referable to any known families. Three new families are formed to contain them, one of which is nearly related to the Dictyoneuridæ with some suggestion of the family Heliolidæ. A second new family is allied to the Heliolidæ, and the third new family to the Homoiopteridæ, or, as the writer believes, near to the Lithomantidæ.

The East Kent insect-remains contain one wing, referable to the genus *Soomylacris* (*Ettoblattina*), a species of which is already known from the Forest of Dean Coal-field.

The finding of two species of the same genus in coal-fields so widely separated as those of the Forest of Dean and East Kent is not without interest, in view of the generally accepted belief in the former continuity of the Coal-measures across the South of England.

CORRESPONDENCE.

THE USE OF THE TERM 'CHARMOUTHIAN'.

Sir,—In the May number of the Geological Magazine for this year, on p. 232, the reviewer of Jukes-Browne's *Students' Handbook of Stratigraphical Geology* says: "The term Charmouthian for part of the Lias (pp. 383, 387) is used for the Middle Lias zones of the Ammonite genera *Paltopleuroceras spinatum* and *Amaltheus margaritatus*, whereas on p. 405 the term is taken to include also the Lower Lias zones of *capricornus* and *armatus*. This is unfortunate and no improvement. *As a matter of fact* [italics mine] the term is inappropriate as no Middle Lias (as above defined) occurs in the cliffs at Charmouth. If used at all the term should be applied to the Lower Lias clays (zones *obtusus* to *capricornus*)."

Surely, if used at all, the term should be applied to the beds included in the Charmouthian by the author of the term. This, according to Renevier,[1] was Mayer-Eymar, who proposed the term in 1864[2] and included within it the same beds as Oppel included in his Pliensbachian in 1858[3] and d'Orbigny in his Liasian in 1852,[4] namely, the zone of *Deroceras armatum* to that of *Paltopleuroceras spinatum* inclusive. Since these zones occur in the neighbourhood of Charmouth, I see no objection to applying the term with its original connotation, as Jukes-Browne appears to have applied it.

By the "Middle Lias (as above defined)" the reviewer presumably means the *margaritatus* and *spinatus* zones. To say that, as a matter

[1] Renevier, "Chronographe Géologique": Congrès Géologique international, Compte-rendu de la sixième session, 1897, p. 572.

[2] Mayer-Eymar, "Tableau synchronistique des Terrains Jurassiques," 1864. I have not verified this reference.

[3] Oppel, *Die Juraformation Englands, Frankreichs, und des Südwestlichen Deutschlands*, (1856)1858, p. 815.

[4] D'Orbigny, *Cours élémentaire de Paléontologie et de Géologie stratigraphiques*, vol. ii, p. 448, 1852.

of fact, no Lias of these zones occurs in the cliffs at Charmouth is untrue, unless "cliffs at Charmouth" is limited to Black Ven. Above a big gully immediately under the western end of Fairy Dell on Stonebarrow Cliff, within a mile of Charmouth Church, a section is exposed showing the Three Tiers at the base of *margaritatus* in place (last seen July, 1911); and, nearer Charmouth, in Stonebarrow Cliff west of the Dell, the lowest Tier with Ammonites of the *margaritatus* group may be seen. Incidentally it may be mentioned that the Three Tiers (as well as the beds immediately below down to the Belemnite Stone) are about half as thick here as at Golden Cap. The western end of Stonebarrow cannot reasonably be excluded from the "cliffs at Charmouth".

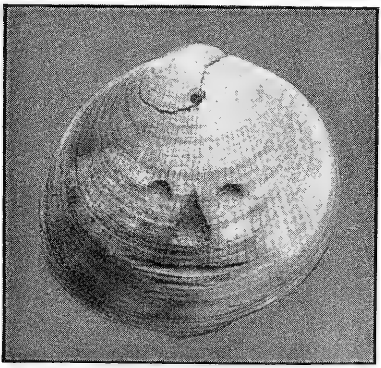
Renevier[1] held that, on account of priority, Pliensbachian should be used rather than Charmouthian. I am not aware that this principle is binding in stratigraphical nomenclature. But, whatever term finally is selected, there is no need either to shift the boundaries of Mayer-Eymar's Charmouthian or to object to the term on the score of topographical inexactitude.

W. D. Lang.

THE RED CRAG PORTRAIT.

Sir,—In the last number of the Geological Magazine (May, 1912) the Rev. O. Fisher figures some of the early handiworks of man. Among these is the sawn bone recorded as from the Crag, which was in Sir Joseph Prestwich's collection for many years and is now in the British Museum.

This reminds one not merely of the Red Crag portrait-shell, in which Sir Joseph was much interested, but accentuates the fact that this shell has never been illustrated. Consequently no figures of it are available for those who are interested, and its appearance is only known to our personal friends and some others who have seen it. Without repeating its history it must be mentioned in explanation



Carved Shell of *Pectunculus glycimeris*, Linn. Red Crag: Walton-on-the-Naze, Essex. Reproduced from a photograph, nat. size.

[1] Renevier, loc. cit.

that in 1881, when it was brought forward by Mr. Henry Stopes at a British Association meeting, it was considered *wrong* to suggest that man could have been alive at so early a date. Mr. Stopes was therefore content to wait till further evidence came to hand before bringing it before a wider public; but his early death left his work unfinished, so the shell has never been figured.

The accompanying illustration is from a photograph and indicates the natural size of the shell; it shows clearly most details of its features except the coloration. It should be noted that the excavated portions are as deeply coloured red-brown as the rest of the surface. This is an important point, because when the surfaces of Red Crag shells are scratched they show white below the colour. It should also be noticed that the shell is so delicate that any attempt to carve it now would merely shatter it.

As, however, the question is still so much under discussion, I wish to do no more now than give a good illustration of the most interesting, though controversial, specimen, so as to make its appearance and detail known to all interested in it. References to the literature will be found in my note in the Geological Magazine for February, 1912, pp. 95–6.

Marie C. Stopes (Ph.D., D.Sc., F.L.S.).

University College,
London, W.C.

OBITUARY.

RALPH STOCKMAN TARR.

Born 1864. Died March 21, 1912.

The sudden death of R. S. Tarr on March 21 last at the early age of 48 has been deeply felt by his many friends on this side of the Atlantic, who held in high regard his sterling personal qualities, as well as his scientific ability.

Born at Gloucester, Mass., Professor Tarr entered at Harvard in 1881, and after interruptions for practical work in marine zoology and for geological field-work in the Eastern and Western States, he graduated in 1891, and in 1892 was appointed Assistant Professor of Dynamic Geology and Physical Geography at Cornell University, and Professor of the same subjects there in 1896, occupying the chair of Physical Geography up to the time of his death. He was married in 1892, and leaves a widow and two children.

In 1896 Tarr had charge of the Cornell expedition to Greenland, which did excellent work; and in 1909 and 1911 he, conjointly with Professor Lawrence Martin, carried out the research expeditions of the National Geographic Society for the study of Alaska glaciers. In 1910 he participated in the Geological Congress excursion to Spitzbergen.

In his university Professor Tarr was recognized as an inspiring and sympathetic teacher, and his untimely death has called forth many touching tributes to his memory from his former students. He was the author of numerous papers and memoirs on physiography, glacial geology, and educational topics, the best-known in this country being his fine monograph for the U.S. Geological Survey on the Physiography and Glacial Geology of the Yakutat Bay Region, Alaska, published in 1909. He also wrote several textbooks of physical geography, geology, and economic geology, which have had a wide circulation.

His arduous field-work in Alaska was resumed last year, and he was engaged in writing up the results and carrying out a series of experiments on the physical properties of ice when death cut short his labours.

Among other honours of recognition outside his own country, Professor Tarr was elected a Foreign Correspondent of the Geological Society of London in 1909.

G. W. L.

CHARLES EDWARD LEEDS, M.A.,

EXETER COLLEGE, OXFORD.

BORN AUGUST 11, 1845. DIED MARCH 27, 1912.

WE regret to record the death at Auckland, N.Z., of Mr. Charles Edward Leeds, M.A., formerly a solicitor in York, who made the early part of the remarkable collection of fossil reptiles from the Oxford Clay of Peterborough which now occupies so large a portion of a gallery in the British Museum (Natural History). Mr. Leeds attended the lectures of the late Professor John Phillips, M.A., F.R.S., and some of his earliest discoveries were described in the Professor's *Geology of Oxford and the Valley of the Thames*, 8vo, 1871, p. 318. Mr. C. E. Leeds left England in 1887 to spend the remainder of his life in New Zealand, and during the past twenty-five years the collection has been remarkably extended by his brother, Mr. Alfred N. Leeds, F.G.S., who still resides at his birthplace, Eyebury, Peterborough.—*Nature*, April 4, 1912.

MISCELLANEOUS.

THE HUMAN SKELETON DISCOVERED NEAR IPSWICH.—At the meeting of the Royal Anthropological Institute (50 Great Russell Street) on April 23, 1912, Professor Arthur Keith, M.D., F.R.C.S., and Mr. J. Reid Moir gave an account of the human skeleton found eighteen months ago in a brickfield near Ipswich.[1] Mr. Moir stated that the bones were earlier than any human remains so far discovered in England, and represented pre-Boulder-clay man. The theory of burial[2] he asserted was not possible, because the line which separated the overlying deposit of Boulder-clay and the underlying stratum of Glacial sand, in which the skeleton was found, was unbroken. The man was lying there before the clay was deposited. The flints found near were of *pre*-Palæolithic form.[3] Professor Keith said the skeleton

[1] See paper by Mr. George Slater, F.G.S., "Human Skeleton in Glacial Deposits at Ipswich," GEOL. MAG., April, 1912, p. 164; also letter by Mr. J. Reid Moir, op. cit., May, 1912, p. 239.

[2] See letter by Professor T. McKenny Hughes, M.A., F.R.S., GEOL. MAG., April, 1912, p. 187.

[3] See "Discovery of Flint Implements beneath the Red Crag in Suffolk", described by Sir E. Ray Lankester, F.R.S., GEOL. MAG., 1911, p. 576.

was extremely ancient, and not that of a Neolithic man. He accepted the geological age ascribed to the bones by Mr. Moir. In the discussion which followed Professor Boyd Dawkins, F.R.S., said that he had just made a careful examination of the section in which the skeleton was found, and he was of opinion that it was *not found beneath* the Boulder-clay as such. The clay was not in situ, but there had been a vertical (earth-)movement in the section. There was absolutely no geological evidence, in that place, of pre-Glacial man. In the case of the Ipswich skeleton there was, he considered, every reason to suppose it was a modern interment. Professor W. J. Sollas, F.R.S., said that the complete truth in such cases could not possibly be arrived at unless experts were called in to examine the bones before they were removed by the workmen.—*Morning Post*, April 25, 1912.

Boring at Puriton, near Bridgwater.—A deep boring in search of coal, carried to a depth of 2,072 feet, during the years 1909–10, by Vivian's Boring and Exploration Company, has lately been described by Mr. James McMurtrie, F.G.S. (Proc. Somerset Arch. and Nat. Hist. Soc., vol. lvii, p. 25, 1911). The site of the boring was 640 yards east of Dunball Station, on the Great Western Railway, and between Puriton Hill and the Sedgemoor Drain. The strata passed through were as follows:—

	Thickness.		*Depth.*	
	ft.	*in.*	*ft.*	*in.*
Superficial (Alluvial) Deposits	23	0	23	0
Keuper Marl with gypsum; and with beds of rock-salt between depths of 646 and 713 feet . . .	1,252	2	1,275	2
Upper Sandstones (Keuper and Bunter).				
Red, grey, and blue marly sandstone, red and grey sandstone, occasional marl, gypsum, and 1 foot of fine conglomerate at depth of 1416 ft. 10 in. . . .	202	8	1,477	10
Bunter Conglomerate.				
Grey and red marly sandstone with bands of conglomerate with limestone pebbles	12	2	1,490	0
Lower Sandstones (Permian).				
Red marly fine-grained sandstones and marl . . .	582	4	2,072	4

The grouping of the Red rocks was made by Mr. W. A. E. Ussher, who remarks that the homogeneous character of the Lower Sandstones for so great a depth is "quite unparalleled in the [Permian] rocks of the south-west of England".

The boring was abandoned because it was considered that if coal were found at a greater depth the seams were not likely to be sufficiently thick to give prospect of financial success, bearing in mind the great cost of sinking.

The undertaking, however, has proved of singular interest and importance by the discovery of rock-salt, the composition of which was sodium chloride 97·47 per cent, calcium sulphate 2·13, calcium chloride ·15, and magnesium chloride ·25. Tests of the brine during five months showed an average yield per gallon of 1 lb. 13 oz. of salt. Some remarkable cores were obtained during the boring of columns of rock-salt encased in red and blue marl. A second boring has been commenced for the purpose or pumping the brine for commercial purposes.

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JULY, 1912.

CONTENTS.

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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. VII.—JULY, 1912.

ORIGINAL ARTICLES.

I.—The End of the Trimingham Chalk Bluff.

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S., and the Rev. E. Hill, M.A., F.G.S.

DURING the last six years the sea has continued to encroach on a part of the Norfolk coast, near Trimingham, which has been the subject of much controversy.[1] Our last visit (prior to this year) was in April, 1906, when the most noted of the chalk masses had been reduced to an arch with one pier of chalk and the other of boulder-clay.[2] That was described (with a diagram), and another account, with a photographic illustration, was given in the same volume by the late Mr. W. H. Hudleston, who apparently had not seen our paper.[3]

In April, 1905, the mass of chalk, so frequently discussed by observers before that date, formed the end of a slight headland, the crest of this descending to it from the general level of the top of the cliffs. At that time two other masses of chalk were visible, rising from the beach near the base of the cliff. These are marked, in the reproduction of Mr. R. T. Mallet's[4] photograph, A (the eastern one), C (the central), and E (the western).[5] In 1905 A still formed part of the spur projecting from the cliffs; C, though less prominent, did the same, while E was separated. In 1906 A had been much reduced in size, and separated to form the 'arch'; C was still in contact with the cliff on its southern side, and E had become rather smaller. (The sketch-plan is reproduced on p. 290.)

The changes which have occurred since that date throw some light, in our opinion, on the question whether the historic 'bluff' (A) was a sea-stack or a detached boulder of chalk. The effect of them may be more easily understood by a description of what we saw last

[1] See this Magazine, 1905, pp. 397, 478, 524, 525; and 1906, pp. 13, 400, 525.

[2] For reasons stated in this Magazine (1905, p. 398) we prefer the name of boulder-clay for this material to that of till.

[3] This Magazine, 1906, pp. 400, 525.

[4] See this Magazine, 1905, Pl. XXII (from a photograph by Mr. R. T. Mallet) and a sketch-plan (made by Mr. Hill at Easter, 1905) published on p. 401 in the volume for that year. They are represented (from slightly different points of view) in the photographs illustrating Mr. Brydone's paper: ibid., Pl. III, Fig. 4; Pl. V, Fig. 10; Pl. VIII, Figs. 13, 14; also Pl. IX, Fig. 18.

[5] For reasons given in this Magazine (1906, p. 570), we use the terms 'east' and 'west' for the trend of the coast as more correct than the 'south' and 'north' of earlier observers.

April. On approaching the site of the 'bluff' along the shore from Cromer, we perceived that not only the arch but also the little headland [1] had disappeared; the cliffs rising from a fairly even base to a height of over 150 feet. On the steep face of one of them we noticed a whitish patch, in form a rather elongated oblong, with its base a very few yards above the beach, the colour of which suggested the presence of chalk. Perhaps a couple of hundred yards before reaching it we came upon a well-laminated dark clay,[2] rising from the beach and running obliquely along it to the base of the cliff. After passing it we found the ordinary 'boulder-clay' of the Contorted Drift group

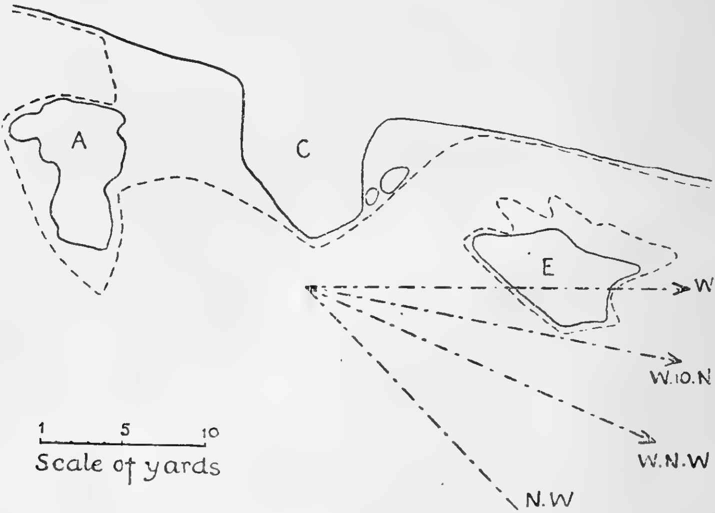


Fig. 1. Sketch-plan (by Rev. E. Hill) of the 'westerly chalk bluff' at Trimingham.[3] The broken line indicates the boundary of chalk or clay in April, 1905; the continuous one that observed on almost the same day in 1906. A, C, E correspond with the masses bearing these letters on Plate XXII, Geol. Mag., 1905, p. 400.

exposed here and there beneath sand or shingle on the shore, and on arriving at the above-named light-coloured patch obtained the following section. The face of the cliff on either side of it, for some little distance, consisted of a yellowish-grey clayey sand, which here, as is locally not infrequent, was less conspicuously bedded than in many places. The light-coloured patch, which was about 16 yards broad at the base and 18 yards or more in greatest height (the cliff at its back recedes just enough to be out of sight when viewed from the shore [4] at a distance of 30 or 40 yards), included on its eastern side

[1] We believe that this was at the Marl Point of the Ordnance Survey map.

[2] It looked like a representative of the Forest Bed group, but we did not happen to see any rootlets or stems.

[3] Reproduced from Professor Bonney's paper in Geol. Mag., September, 1906, p. 401.

[4] The tide had not risen much on the occasion of our second visit, when photographs were taken.

a mass of chalk, but mainly consisted of a rather peculiar gravel, formed of irregularly alternating beds, more or less streaky or lenticular, of pebbles and sand (Fig. 2); the latter in one or two places attaining a thickness of 15 or 16 inches, and being fairly free from stones. This and the matrix of the former is a light-coloured quartz-sand, occasionally having more chalky streaks. The fragments of the gravel are mostly chalk and flint. Those of chalk are of two forms, the less numerous being rather well rounded, ranging up to about 4 inches in diameter; but the majority 'tabular' in shape, with

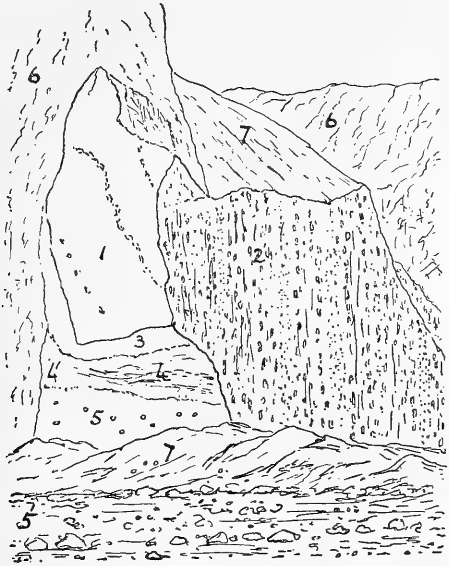


FIG. 2. Diagram of boulder of chalk and associated gravel in Contorted Drift (with Boulder-clay) near Trimingham. Explanation: 1, Chalk with flint. 2, Gravel with sandy beds, bedding nearly vertical. 3, Grey clay. 4, Irregularly banded sand and clay; 4 feet sand. 5, Boulder-clay; 5 feet. Boulder-clay showing on beach in many places. 6, Ordinary clayey sand of Contorted Drift. 7, Slip.

corners and edges somewhat worn, the longer diameter being not infrequently about 5 or even 6 inches. These slabs, since the bedding is now vertical, give a marked character to the gravel. The pieces of flint vary from angular to moderately rounded, and any so much as 4 inches in diameter are rather uncommon. The embedded boulder of chalk contains two distinct layers of flint, the lower more strongly curved than the upper, with indications, as we think, of a third one nearer to the base.[1] This mass and the left-hand part of the gravel

[1] The gravel and the attached chalk are to be seen (though, of course, less clearly than now) on Figs. 10, 11, Pl. V (Brydone, loc. cit.). These indicate that it must have been a few yards farther from Cromer than the right-hand mass of chalk (that marked E in the Plate illustrating our paper in this Magazine for 1905, Plate XXII), or about north of the east end of E in the plan on p. 401

apparently rest on a sort of cushion of stratified clay and sand, the bedding of which in the upper part appears to be rudely conformable with the exterior of the composite boulder; for it first slopes downwards rather steeply (at any rate in the upper part) and then becomes more nearly horizontal. This 'cushion' and the bottom of the gravel rest on a boulder-clay corresponding with that exposed on the beach.[1] The junction on the right-hand side is hidden by a little slipped material, but as the banded clayey sand seems to be thinning in this direction the gravel mass very likely rests at last on the boulder-clay. About 30 yards to the east of this great composite boulder, we found a curious vein-like mass of chalk rising from the beach and running obliquely (westward) for a few yards up the face of the cliff. A layer of coarse gravel adheres to part of its upper surface, and some boulder-clay was seen sticking to the bottom in one place. That clay is also exposed at a distance of a few feet beneath the clayey sand which encloses this chalk.

On the beach, about 30 yards from the base of the cliff, on a line drawn perpendicular to it about half-way between the other two masses, a third piece of chalk was seen rising for only a few inches above the beach, which may be described as a segment of a circle with a chord of about 10 yards and a sagitta, pointing at the cliff, of about 4 yards. Boulder-clay was clearly exposed about it, and appeared to pass beneath its edge, so that we judged the chalk to be a thin slab, the relic of a much thicker boulder. Its position and distance from the cliffs inclined us to the view that it was the last remnant of the historic mass, which in 1906 was reduced to the northern pier of the arch. East of this spot, chalk, obviously in situ, is exposed on the beach within a few dozen yards, so it would probably be struck at a small depth, perhaps hardly a yard, below the base of the cliff.

A word may be added about the two rather long chalk masses, which rise from the shore a few hundred yards nearer Mundesley. They also have suffered from the attacks of the sea, which has washed out a small cove between them. The western one now seems to have its eastern end distinctly pointed—a fairly acute angle, with drift below as well as above—and to be slightly farther away from the sea than the western end of the other mass. The face of that rises directly from the beach, but its eastern end has been worn by the waves into an irregular reef some yards in length, nowhere more than a very few feet above the shore. So that we seem justified in regarding as erratic even these great slab-like masses which formerly suggested the possibility of their being low stacks on a pre-Glacial surface of the chalk, similar to but more prominent than the slight prominences east of Sheringham.

The evidence which has been disclosed by the invasion of the sea

of the volume for 1906, and reproduced here on p. 290, Fig. 1. Our notes in 1905 and 1906 record the presence of a gravel boulder and of what might be chalk, but as the former was not well exposed, and their full bearing on the question could not then be appreciated, we did not mention them.

[1] It was well seen here, and we thought the chalk pebbles became a little less numerous in the middle part of the exposure.

during the last twenty years justifies (in our opinion) the following conclusions:—

A little to the east of the Trimingham section, chalk, with a fairly level top-surface (like an old sea-floor), lies only a few feet below high-water mark. Hereabouts it is covered by a normal boulder-clay, which at this place forms the base of the Contorted Drift, without remains of the Forest Bed or Weybourn Crag. This clay, as a whole, contains many boulders, some of solid, some of *remanié* chalk, and occasionally one of sand and gravel, and we now seem justified in concluding the Trimingham masses to be erratics, not ancient stacks of chalk.

Though the gravel mass at Trimingham is, in at least one respect, unique, we meet occasionally with boulders of stratified sand or gravel. In 1892 there was one, also with its bedding vertical, in the cliffs to the west of Cromer. It had practically disappeared before our next visit, and the place, not far from the end of the lower promenade, is now overgrown with grass.[1] This was a more normal sandy flint-gravel than that at Trimingham, and it contained numerous fragments of marine shells. It was in the usual bedded clayey sands of the Contorted Drift, and so far as we remember was some 40 feet (perhaps more) above the sea. In one respect these gravel and sand boulders are interesting, for the material is incoherent; one could bring it down rapidly with a rake. It therefore could not have been transported unless it had been frozen into a solid mass. In other words, it must have been saturated with water and that have been converted into ice. If it tumbled from a cliff upon an ice-sheet, we are forced to assume that either the latter must have been very thin or the former very high. For an ice-sheet to pluck up from the sea bed a block of this shape would be difficult and still more so to turn it from a horizontal to a vertical position. If we could assume it to have fallen from a cliff upon an ice-foot, and to have been floated away for some little distance, the problem would be simplified, but if so (or in the other case named above) the cliff can hardly have been situated north of the present positions of the boulders, for that hypothesis introduces obvious difficulties. Be this as it may, we need a low winter temperature to convert into solids masses so large as these. It cannot have been less, and may well have been more, than in Spitzbergen at the present day, where the January temperature is about —10° F. with a mean annual temperature of about 18°. That of the Norfolk coast in the Cromer district is about 30° for mid-winter, with a mean annual temperature of about 49°, so there must have been an approximate drop in the one case of 40°, in the other of 31°, which imply a greater fall than is demanded by the indications of the Glacial Epoch in the more central parts of Europe.[2] But to discuss that interesting topic would unduly lengthen this paper, so we must restrict ourselves to calling attention to the above-mentioned facts, and hope to consider them more fully on a future occasion.

[1] So far as I remember, it approached 20 feet in length, and was at the base a little wider than that, but I could not do more than make a rough sketch of it as I was going back to my hotel to return to London. (T. G. B.)

[2] T. G. Bonney, Brit. Assoc. Rep., 1910, pp. 22, 23.

II.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from the April Number, p. 147.*)

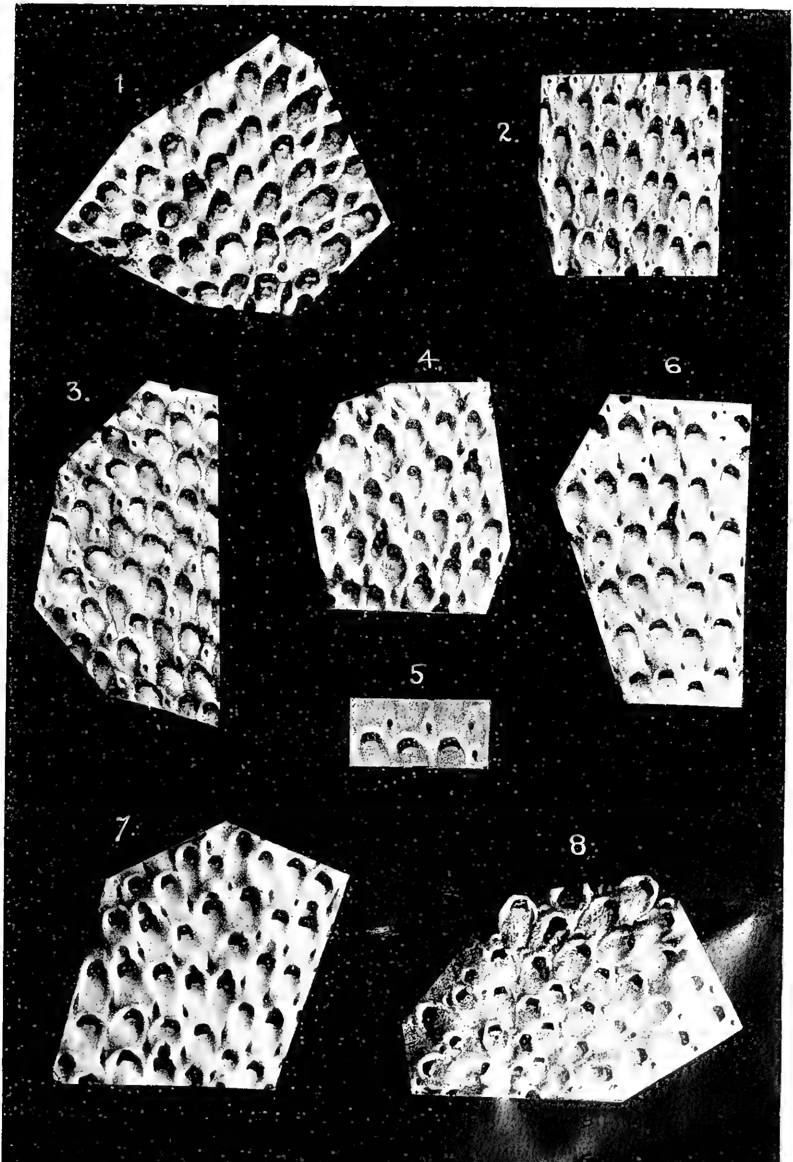
(PLATES XIV AND XV.)

Semieschara Proteus, sp. nov. (Pl. XIV, Figs. 1–8.)

Zoarium always encrusting, with a very strong tendency to linear and in particular transversely linear arrangement, the great regularity of occurrence and the smallness of the avicularia being unsuited to the quincuncial arrangement usual among the Escharidæ.

Zoœcia. If I am right in the extent I assign to this species the range of variation is abnormally wide. The typical form of zoœcium is that met with in the zone of *M. cor-testudinarium*, and exemplified by Figs. 2–5; here the zoœcia are notably long and narrow, ·5 mm. long by ·28 mm. wide being average dimensions; the aperture is small, terminal, and semicircular, but with its sides slightly straightened and its top slightly flattened, and its lower lip is usually gently convex, but also varies between strongly convex and practically straight; the front wall is nearly but not quite flush with the side walls at the foot of the zoœcium, but sinks steadily towards the aperture, and its surface often gives a suggestion of roughness. In the zone of *M. cor-anguinum* (Figs. 6 and 7) the zoœcia are of the same general type, but are wider in proportion, with average dimensions of ·52 mm. in length and ·35 mm. in width; the front wall not only rises flush with the side walls at the foot of the zoœcium but often swells up above them, while it sinks to a greater depth at the aperture and is smooth almost to sleekness; the lower lip of the aperture still varies between strongly convex and practically straight, but the *average* convexity is less than in the preceding zone. In the very rare form from the zone of *H. planus* illustrated by Fig. 1 the zoœcia are of quite different shape, ·55 mm. long by ·4–·45 mm. wide being average dimensions; the front wall is well below the side walls at the foot of the zoœcium and sinks but little towards the aperture, and its surface is strongly roughened; the aperture is large and its lower lip projects very prominently, leaving a deep, wide, blunt-ended sinus on either side of it. In the upper part of the zone of *A. quadratus* there occurs quite rarely the form illustrated by Fig. 8; here the zoœcia have very similar dimensions to the *planus* form and also its rough front wall, but the front wall rises above the side walls at the foot of the zoœcium, though even so it is still below the end wall of the preceding zoœcium, and it sinks moderately towards the aperture, which is large and has its sides distinctly straightened by what appears to be a definite infold of the side wall, and a lower lip, which is either practically straight or only slightly convex; in this form alone is there any tendency to separate side walls for adjoining zoœcia.

Oœcia small depressions in the foot of the succeeding zoœcia, but embraced by the end wall and covered in with an inconspicuous narrowly heel-shaped roof with a concave free edge; they occur frequently, but are generally only evidenced by the bulged end wall



R. M. Brydone, Photo. Bemrose, Collo.

Chalk Polyzoa.

at the head of the zoœcium with a depression between it and the aperture; in the *quadratus* form they are exceptional, being large and globular.

Avicularia small, mandibular, very abundant, and typically placed interstitially at every meeting-point of four zoœcia, with the beak directed upwards, and generally, but not (e.g. Fig. 3) invariably, in the zones of *M. cor-testudinarium* and *M. cor-anguinum* fused with the surrounding zoœcia. In the zone of *H. planus* they are wide (about ·3 mm. at maximum width) and stumpy with circular apertures, from the lower side of which a slender sinus runs a short way downwards in the middle line. In the zone of *M. cor-testudinarium* they are reduced in width by about half, the side walls rise considerably, the beak when distinguishable is long and narrow, and the aperture is smaller in proportion, definitely elliptical, and often without sinus, the latter when present being much reduced in length. In the zone of *M. cor-anguinum* the lateral compression has increased to a point at which they are often little more than wide cracks between the zoœcia; the aperture when visible is still elliptical, but narrower, and shows no trace of a sinus. In the zone of *A. quadratus* the avicularia are apparently much shorter and wider again, but one of the side walls seems to have been squeezed upwards and inwards until it almost wholly overhangs and conceals the aperture; the outlines of the avicularia are very faint and uncertain.

The early and late forms of this species differ so markedly from the general type that they might easily be treated as separate species, and it is only the progressive series afforded by the avicularia which has decided me to act on a strong general impression that they are all variations of one very plastic species. I propose, however, for the present to distinguish the *planus* form as var. *lateaperta* and the *quadratus* form as var. *peneclausa*.

The form described by D'Orbigny as *Reptescharinella transversa* comes near this, but is easily distinguishable by the avicularia pointing downwards.

Semieschara Woodsi, mihi.[1] (Pl. XV, Figs. 1–5.)

Semieschara Pergensi, mihi.[1] (Pl. XV, Figs. 6–11.)

I take this opportunity of giving photographic figures of these species, as the original figures, which were based upon my probably diagrammatic sketches, are not very adequate. In each case the type is unfortunately not well adapted to photography, and has required to be supplemented by other specimens. In the case of *S. Woodsi* I am now convinced that what I described as the upper lip of the aperture sloping sharply inwards is the upper surface of the butt end of the succeeding zoœcium, visible within the upper part of a large semicircular aperture; round pores are sometimes visible in its end wall, and this is well shown by several zoœcia of the type-specimen, which was therefore specially lighted to bring out this feature as far as possible. The aperture of the avicularium seems very variable both in size and shape, the prevailing shape being elliptical, not

[1] Geol. Mag., July, 1906.

circular. The earlier forms have as a rule sharper features than the later. The oœcia (Fig. 5) are very simple, very little more than mere swellings.

In the case of *S. Pergensi* the original figure was quite inadequate and must be withdrawn. The type was unfortunately selected from a horizon at which various delicate features presented by the early forms had got blunted or obscured. In the early forms from the lower part of the zone of *A. quadratus* the zoœcia are separated by definite sutures which enable a distinction to be easily drawn between the not infrequent accidental swellings of the foot of a zoœcium, which stop short at the suture, and the rather larger swellings which pass across and hide the suture and are oœcia (Fig. 9); the little infolds of the side walls, which give a trifoliate appearance to the aperture, are sharp and strong in the early form, but tend to die away in the later forms, as e.g. in the larger zoœcia in the figure of part of the type, though occasional specimens and zoœcia continue to develop them well (e.g. Figs. 7 and 8). The avicularia in the early forms prove to be of the hourglass type, with a long elliptical aperture and side walls gently infolded over a considerable length, and at their maximum of infold slightly overhanging the aperture, below which point they return rather sharply; a tiny blunt denticle is often found projecting into the aperture from the middle of its lower end; the bounding sutures (slightly exaggerated in the figures) show that a deep cavity is hollowed out in the lower end of the succeeding zoœcium in order to receive the low upper end of the avicularium. In the later forms the avicularia tend to broaden and flatten out and the infold of the side walls and the apertural denticle become very faint or disappear.

EXPLANATION OF PLATES.

Plate XIV.

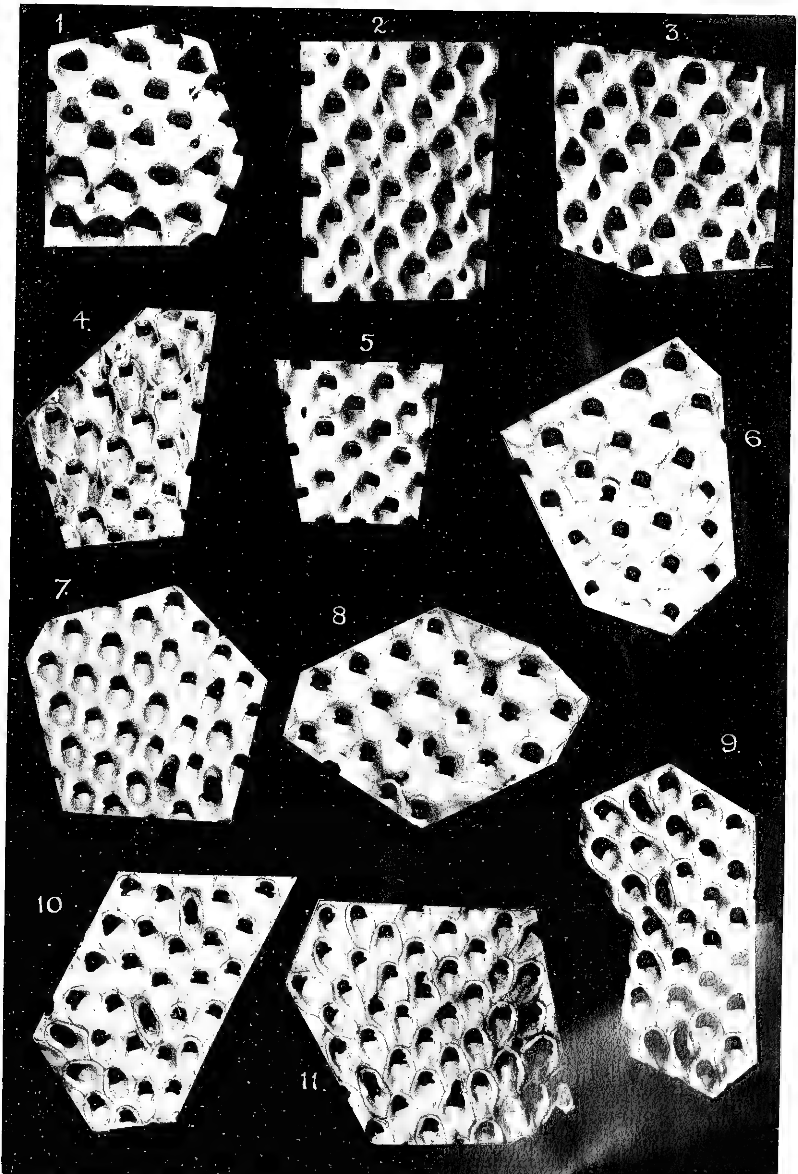
(All figures × 12 diams. unless otherwise stated.)

Fig. 1. *Semieschara Proteus*, var. *lateaperta*. Zone of *H. planus*, Froxfield, Hants.
,, 2. *Semieschara Proteus*. Zone of *M. cor-testudinarium*, Seaford.
,, 3. ,, ,, ,, Privett, Hants.
,, 4. ,, ,, ,, Seaford.
,, 5. ,, ,, ,, ,, × 21.
,, 6, 7. ,, ,, *M. cor-anguinum*, Gravesend.
,, 8. *Semieschara Proteus*, var. *peneclausa*. Zone of *A. quadratus* (subzone of ditto), Shawford, Hants.

Plate XV.

(All figures × 12 diams.)

Fig. 1. *Semieschara Woodsi*. Zone of *B. mucronata*, Portsdown (type-specimen).
,, 2, 3. ,, ,, ,, ,,
,, 4. ,, Subzone of *O. pilula*, West Meon, Hants.
,, 5. ,, ,, *A. quadratus*, Shawford, Hants.
,, 6. *Semieschara Pergensi*. Zone of *B. mucronata*, Portsdown (type-specimen).
,, 7, 8. ,, ,, ,, ,,
,, 9–11. ,, Subzone of *E. scutatus*, var. *depressus*, Brighton.



R. M. Brydone, Photo. Bemrose, Collo.

Chalk Polyzoa.

III.—A New Species of *Fibularia* from Nigeria.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

(PLATE XVI.)

Among a series of fossils collected in Southern Nigeria by Mr. A. E. Kitson, and submitted by him to the authorities at the British Museum, are some small Echinoids. Dr. Bather has kindly allowed me to examine them, and, as they appear to belong to a new species, I have drawn up the following description. For reasons stated below I ascribe the forms to the genus *Fibularia*, Lamk., and consider all the specimens to belong to the same species. Ten individuals have been used for the purposes of the description, but, to prevent possible confusion, I select that numbered A as the type-specimen.

All the examples are preserved in a pale-yellow, calcareous sandstone of fine grain. Unfortunately the sand grains have often been pressed into the tests, leaving a scarred surface on which it is difficult to trace tubercles or sutures with any certainty. By staining some of the specimens with aniline green, the pores of the ambulacra, the tubercles, and to some extent the plate sutures, were rendered visible, and all the details of structure given below are taken from those examples (Nos. A, B, E, G, H, and K).

Fibularia nigeriæ, sp. nov.

The following are measurements (in millimetres) of the nine complete specimens examined:—

	Ant.-post. diam.	Transv. diam.	Height.	Length of ant. petal.
A . .	8·8	7·8	8·1	2·8
B . .	11·1	10·8	10·4	3·0
C . .	8·8	7·1	7·1	2·5
D . .	10·0	8·6	9·0	3·1
E . .	7·2	5·7	5·9	2·0
F . .	8·9	8·1	7·5	?
G . .	7·6	7·2	7·0	2·1
H . .	6·7	6·1	5·7	2·1
J . .	7·9	7·4	7·1	?

Shape.—As the above measurements show, the shape of the test varies very considerably. Individuals may be either elongated or approximately circular, without regard to their size, so that the ambital outline does not necessarily show a change in character during growth. All the specimens agree in being to some extent longer than broad. The test is extremely elevated, having usually almost the same height as breadth; while, in the most elongated examples (A and D), the height actually exceeds the breadth.

The apex of the test is central, and coincides in position with the madreporite. From this point the test slopes down gradually for a distance corresponding closely with the length of the ambulacral petals. Beyond that region a very sudden increase in declivity appears, and the walls of the test become almost vertical. It is impossible to ascertain where the adoral surface begins, as the margin of the test is perfectly rounded. The maximum diameter is at a level approximately two-thirds of the distance from the apex to the base. In the forms which approach most nearly to a globular shape, there is a tendency to a slight flattening of the adoral surface over an area whose radius is the line from the centre of the peristome to the adapical margin of the periproct. There may even be a slight concavity in this region. But in the elongated forms no such flattening is developed, so that the specimens will not stand on the adoral surface, but lie on one side.

An important feature which is shared by all the specimens is the carinated character of the ambulacra, and a consequent alternation of concavity and convexity in the ambital outline, comparable with that of many species of *Clypeaster*. (This is shown, to a slightly exaggerated degree, in Pl. XVI, Fig. 4.) The interambulacra are slightly sunken, chiefly along their median sutures, and the perradial parts of the ambulacra are equally depressed. But on the ambulacral areas, less than half-way between the interradial and perradial sutures, a more or less prominent elevation passes down from the ends of the petals almost to the peristome. The carinæ are more prominent in the elongated forms, but are quite obvious even in the most spherical.

The Ambulacra.—The ambulacra are petaloid for from eight to fourteen of their plates from the apex (according to the size of the specimens), and increase considerably in width below the petaloid region. They become rapidly narrower below the ambitus, but occupy most of the peristomial margin. The width of the ambulacra is to that of the interambulacra (measured at the ambitus) as 5 : 3.

The posterior petals are very slightly shorter than the others, and in elongated specimens the lateral ambulacra are perforce shorter than the anterior. The plates are all primaries, but are often cuneiform. The petals are in a few instances slightly, but definitely, inflated, but are usually flush with the test surface. The number of pores in the petals shows an increase, following the growth in size of the individuals, but slight variations in the number (of quite an irregular type) often occur in the petals of a single specimen. The pores are rounded or elliptical, no regular difference being shown between those of the outer and inner series. They are very large in proportion to the size of the test. The two pores of a pair are set obliquely, sloping interradially and adorally, and are joined by a shallow groove of a width equal to the diameter of the pores. The obliquity of the pore-pairs becomes more intense as they are traced outwards from the apex, so that the inner row of pores is more closely packed than the outer. The last three or four pore-pairs on each half area pierce a more perradiad part of the plate than the upper series. This gives a tendency to a closing of the petals, a feature which is more apparent than real, as it is exaggerated by the extreme obliqueness of the distal pore-pairs.

As far as I have been able to ascertain, there are no other pores in the petaloid region of the ambulacra, nor any pores like those of the petals in any other part of the areas excepting on the peristomial margin.

Below the petaloid part of the areas the plates become considerably larger, increasing in both height and width. At the end of the petals the transverse sutures are practically horizontal, but below the ambitus they become oblique to a variable degree, sloping downwards towards the interradial margins of the areas. The height of the plates remains constant throughout the non-petaloid region. On the actual border of the peristome, one pair (rarely two pairs) of pores occur in each ambulacrum. These pores are not quite so large as those of the petals, and only become visible when the specimen is stained.

On all the plates from the petals to the peristome, there occur, instead of the normal pore-pairs, rows of minute perforations similar to those in *Echinocyamus pusillus* and many other Clypeastroids. The main series of them form transverse rows, parallel with, and immediately adoral to, the transverse sutures. Towards the interradial sutures these rows curve slightly in an adoral direction, and mingle with scattered pores (often grouped obscurely in sets of three) which occur over the whole plate area. The relations of these small pores are shown in Pl. XVI, Fig. 9. They can only be seen in stained specimens, and then usually with difficulty. On slightly etching one example with acid, their disposition was clearly shown. The figure is adapted from that specimen, the tuberculation being inserted from a different individual.

The Interambulacra.—Between the petals the interambulacra are very narrow, and, through almost half that region, are composed of single deltoidal plates bearing vertical rows of tubercles. The areas widen out towards the distal end of the petals, but are soon narrowed by the renewed expansion of the ambulacra. The plates are, for the most part, rather higher than broad, and one of them corresponds to rather more than two of the extra-petaloid ambulacrals. The tuberculation is sparse, and uniform in character. The tubercles are deeply scrobiculate, and appear to be imperforate. On the adoral surface the interambulacra become rapidly narrowed towards the peristome. I have not been able to trace the plate sutures with certainty in this region of the test, but the evidence seems to indicate that there is a single, narrow plate separating the ambulacrals on the peristomial margin, as in the majority of the Clypeastroida.

The Peristome.—The peristome is central and small, being only 0·9 mm. in diameter in specimen B, the largest examined. It is obtusely pentagonal in outline, the angles of the pentagon corresponding to the radii. The mouth opening is wider on the outer surface of the test than within, and on the bevelled edge of the peristome one, or more rarely two, pairs of large pores are situated. (In specimen B there seems to be a single pore only in each ambulacrum, proportionately larger than in cases where two pores exist.)

The Periproct.—The periproct is situated about midway between the peristome and the ambitus (when measured tangentially). It is always smaller than the peristome. The aperture is almost circular in most cases, sometimes showing a slight elongation in the direction of the interradial suture. The test is thinner than at the peristome, and the edges of the periproct show no trace of bevelling.

The Apical System.—The apical system is central, and, as is usual in Clypeastroids, shows no signs of the plate sutures. The madreporite is in the centre of the system, and is prominent. It is multiporous. the greatest number of perforations being congregated in its posterior part. There are four genital pores, all considerably larger than those of the petals. They pass through the test at the same distance from the apex as do the proximal petal-pores, so that either they are at the outer margins of the genital plates, or else the latter project considerably into the interambulacra. The ocular pores are very minute, and can with difficulty be seen, even after etching with acid and staining the specimen. They are slightly sunken below the surrounding level of the test.

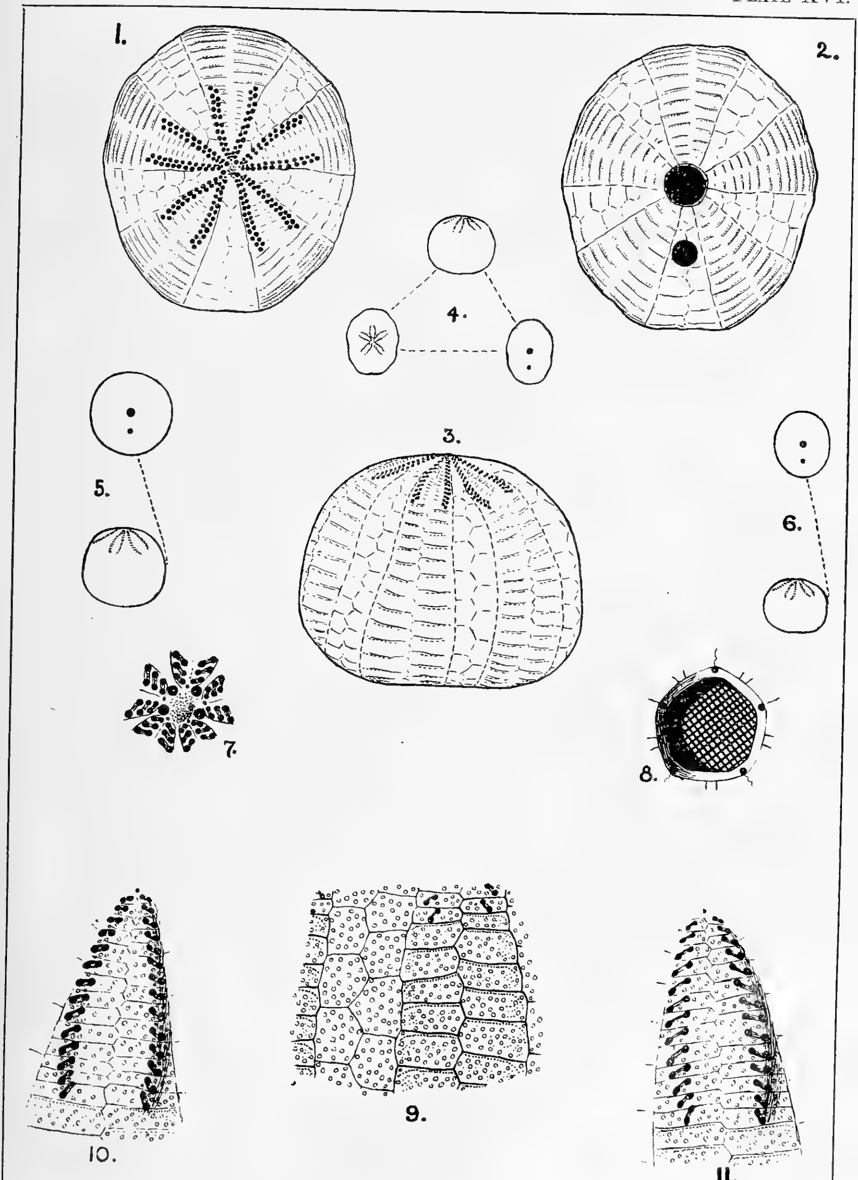
Comparison with other species.—In view of the fact that all the specimens are very much elevated, and the broken specimen (K) shows no trace of interradial buttresses, I refer the species to *Fibularia* as Clark has recently defined the genus (Ann. Mag. Nat. Hist., ser. VIII, vol. vii, p. 605). Probably, if any sound generic distinction separates the *Thagastea* of Pomel from *Fibularia*, it should join the former group; but I am not satisfied that the genus is distinct. The only anomalous feature in *F. nigeriæ*, which renders its generic position doubtful, is the slight inflation of the petals, and the shallow grooves which connect the pores in that region. It is possible that this may mark an important difference, since the opposite conditions prevail in most *Fibulariæ*, but with the material available it seems best to admit the species to that genus.

The only species with which I am acquainted that bears any close resemblance to *F. nigeriæ* is the *F.* (*Thagastea*) *luciani* (de Loriol, 1880), originally described from the Middle Eocene of Egypt, and recently discovered by Dr. J. W. Gregory at the same horizon in Cyrenaica. The proportionate height (compared with the length) of *F. nigeriæ* is, however, persistently greater than in either de Loriol's or Gregory's specimens. Adding to this extreme elevation of the test the peculiarities of the petals and the carinate shape of the test, sufficient contrasts exist to distinguish at once the Nigerian species from *F. luciani.* These same features serve to separate *F. nigeriæ* from all other species of the genus, since *F. luciani* is the most elevated of all previously described.

Locality and Horizon.—The specimens were collected at Bende, Southern Nigeria.

The exact horizon of *F. nigeriæ* cannot be ascertained. It might well be ascribed to the Lower Tertiary, probably Lower or Middle Eocene, since the genus *Fibularia* was apparently not well established before then. The elaboration of the petals tends to support the view that it is by no means the earliest species of the genus. It is, however, within the bounds of possibility that it may be of Maestrichtian age, though its general characters render it more likely, to my mind, that it belongs to a later horizon.

The specimens are preserved in the Department of Geology, British Museum (Natural History).



H. L. Hawkins del.

Fibularia Nigeriæ, sp. nov. ? Tertiary, Southern Nigeria.

EXPLANATION OF PLATE XVI.

FIBULARIA NIGERIÆ, n.sp.

FIG. 1. Adapical surface of A (type-specimen). × 4·5.
,, 2. Adoral surface of A. × 4·5.
,, 3. Lateral view of A. × 4·5.
,, 4. Same specimen. Nat. size.
,, 5. Specimen B. Nat. size.
,, 6. Specimen C. Nat. size.
,, 7. Apical system of B. × 12.
,, 8. Peristome of B. × 12.
,, 9. R. post. amb. and iamb. of K. × 9.
,, 10. Ant. petal of B. × 9.
,, 11. Ant. petal of A. × 9.

IV.—NOTES ON DESERT-WATER IN WESTERN AUSTRALIA. 'GNAMMA HOLES' AND 'NIGHT WELLS'.

By MALCOLM MACLAREN, D.Sc., F.G.S.

IN the arid region of the goldfields of Western Australia a knowledge of the conditions under which a search for water is most likely to be rewarded is of prime importance to the prospector who may find himself away from the beaten tracks. There is, in the summer, little hope of finding fresh water in the long narrow bands of gold-bearing greenstone-schist that run from N.N.W. to S.S.E. through Western Australia, for both the surface and the deep-seated waters of this rock-formation are then salter than those of the sea. When unprovided with 'condensers' for the distillation of these waters, the prospector must therefore turn towards the neighbouring granitic areas, and search either for 'soaks' or for the remarkable 'gnamma'

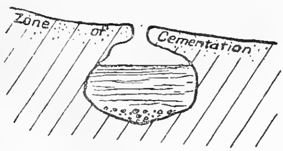


FIG. 1. Cross-section of typical 'Gnamma' hole.

holes of the bare rocky ridges. The first and most reliable of these sources of fresh water—the 'soaks'—presents nothing abnormal and requires little description. They are found in the sandy hollows at the foot of granite slopes. A well is sunk in the sand, and the water is baled as it slowly percolates into the bottom of the hole. The supply may vary from a mere trickle to several hundred gallons in twenty-four hours, according to the catchment, to the season, and to the permeability of the sand that has protected the water from evaporation since it was collected in the rock-hollow.

Where the absence of soaks is indicated by the non-appearance of the slightly greener vegetation that grows over them, the traveller abandons the lower ground and searches the bare rock-outcrops for rock-holes, or 'gnamma' as they are called by the natives.

Gnamma holes are most common in granite areas, but are occasionally to be found in the quartz-porphyry and soda-porphyry dykes that seam the greenstone-schists. Somewhat similar rock-holes may occur in the lateritic deposits that mask the greenstone-schists, but they are there very rare. The normal shape is usually that of an ordinary water carafe, having a comparatively narrow cylindrical orifice and widening out greatly below (Fig. 1). Their capacity varies from a few gallons to several hundreds and even thousands of gallons, and several may be found on the one rock slope. Like the soaks they are dependent on the rainfall of the previous winter. Under favourable circumstances they may obtain sufficient water to last throughout the summer, but they cannot, in individual cases, always be relied upon. The scanty rains of the eastern desert are erratic in distribution, falling always as a few heavy local showers, so that a given rock slope may escape the rains of a whole winter. The water of these gnamma holes, forming as it does the principal summer supply of the wandering aboriginals, is carefully preserved by them both from evaporation and from marsupials, reptiles, and birds, by covering the water with eucalypt foliage, and the orifice with flat stones.

The occasional occurrence of these peculiar rock-holes at the intersection of or along joints in massive granite gives some clue to their origin. They apparently arise in the first place from the flaking off by insolation of small fragments along the walls of the joint. In the cavity thus formed (generally on a smooth sand-swept rock surface) a little water lodges, in time decomposing the felspathic member of the rock, and freeing the quartz-grains which are swept from the shallow depression by the high winds of the desert. Seasonal repetition of this process slowly deepens the hole beyond the reach of the wind. The sand now retains the water, and the sides and the bottom of the cavity are alone attacked, and the hole grows in size horizontally and vertically. The orifice is protected from enlargement partly because there is no standing water to act on its sides, but much more because of the siliceous cementation that has taken place at and near the rock surface in its neighbourhood, as a result of the upward capillary movement of the silica dissolved in the course of the decomposition of the felspars of the granite. This superficial cementation is characteristic of this desert region, and has its utmost expression, as I propose to show in another place, in the formation of beds of siliceous 'laterite' 30 and 40 feet thick, comparable in respect of origin with the ferruginous laterites of the greenstone-schist areas. To it must be ascribed the unique form of these granite rock-holes. The process of internal enlargement has probably been greatly accelerated by the removal of the sand from the bottom by human agency, since the position of all these rock-holes is well known to the aboriginals, who, indeed, govern their migrations by the location and capacity of the various gnammas.

In the camp-fire conversation of the West Australian prospectors and cattlemen, the all-engrossing subject is water, and, when on this topic, it is seldom long before the 'night wells' are mentioned (Fig. 2). These are described as rock-holes dry by day, but furnishing an abundant supply of water at night. They are regarded as mysterious and indeed somewhat uncanny, since their nocturnal flow is always preceded by weird hissings and by hollow sounds of rushing air. Certainly no explanation of the undoubted fact that water appears in them at night only, during the summer season at any rate, has, so far as I know, yet been advanced. How many 'night wells' there are I have never been able to ascertain. The cattlemen speak of several, but are hazy as to their geographical position. In March, 1911, I had an opportunity, while driving across country from Ravensthorpe to the railway station at Broomehill, in the south-western portion of the State, of visiting for a few minutes the only night well whose position I could definitely fix. It lies between Magitup and Cowallellup (Carollillup) in lat. 34° 5′ and long. 118° 25′.

The 'well', or rather rock-hole, is situated on the top of a rounded boss of platy granite-gneiss, standing from 6 to 8 feet above the bed of a stream of the usual West Australian type, the course of which is marked across the plain by a double line of large she-oak and paper-bark trees. Along the sandy creek bed were several pools of salt water, from which the salt was beginning to crystallize out on the margins, for it was then long since rain had fallen. I had

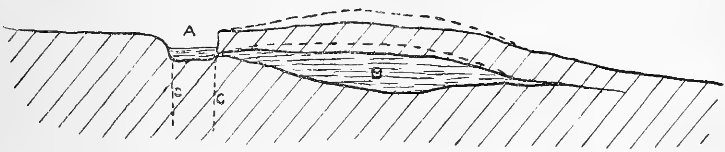


FIG. 2. Cross-section of 'Night Well'. A, trough; B, internal cavity; C, C, vertical joints.

expected to find in the night well an ordinary gnamma hole, but it differs materially from these. Across the boss there ran two vertical joint-planes, 2 feet apart at the widest portion exposed, but almost meeting at the other end of the bare rock surface, which was some 60 by 30 feet in area. For a length of 15 feet the rock between these joint-planes has been removed, yielding a trough with a width of from 18 to 30 inches and a maximum depth of $2\frac{1}{2}$ feet. Throughout the summer this trough is empty by day, but contains from 12 to 18 inches of water at night. Near the bottom of the trough, and in the rock wall of one side, was a horizontal rift extending the whole length of the trough, and marking the plane of separation of a thin surface plate of gneiss from the main mass below, and it was through this rift that the water appeared and disappeared. The platy granite-gneiss here found is by no means common in Western Australia. This, indeed, is the only spot at which I saw it during traverses covering many hundreds of miles. It is, however, recorded by the Geological Survey from near Northampton, and also in the Gascoyne and the Pilbara region in the north-west of the State. While a portion of the water contained in the cavity that clearly exists beneath the surface-shell of gneiss is probably derived from the rainfall caught on the bare rock surface, the top of the gneiss boss is yet not too high above the stream bed to be beyond the reach of the flood waters arising from the few torrential storms in which the whole annual rainfall (12 inches) of the district falls. No other features bearing on the problem were observed; still, these facts and the attendant climatic conditions are sufficient to indicate a feasible explanation of the phenomenon.

The shell of gneiss, except beneath and at the side bordering on the trough, is in continuity with the mass of the rock. The diurnal range of temperature on the rock surface is considerable in the summer—certainly not less than 100° F. During the day the shell of gneiss, prevented from horizontal expansion on three sides, springs to an arch, and the water in the trough retreats—probably entirely by gravity—through the rift. At night, with a considerable fall in the rock temperature, the shell contracts, and settling down, forces, firstly, air through the narrow irregular rift (hence the whistling and hissing sounds that for half an hour precede the appearance of water in the trough) and finally water, which reaches its maximum height in the trough about daybreak. The first appearance of the water generally occurs about 8 o'clock at night. The expulsion of air prior to that of the water indicates that the water is withdrawn within the rock by gravity and not by any siphon effect. Since the linear expansion of gneiss is approximately only one part in 200,000 for every degree Fahr., the cavity must be large and the adjustment of level fairly delicate. This, indeed, is also indicated by the fact that, for some time after heavy rains, water remains during the day in the outer trough. In the absence of any evidence of displacement of the outer shell of gneiss, it may be assumed that the internal cavity has been assisted in reaching its obviously large dimensions by disintegration of its walls in the same manner that a gnamma hole grows.

V.—On the Recognition of Two Stages in the Upper Chalk.

By A. J. Jukes-Browne, F.R.S., F.G.S.

When writing a general account of the Upper Chalk of England for vol. iii of the *Cretaceous Rocks of Britain* (Mem. Geol. Survey, 1904), I stated the belief of Mr. W. Hill and myself that the British Upper Chalk comprised more than one division of the value of a stage. We grouped the zones then recognized into two divisions, pointing out that the lower zones were essentially the Chalk with Micrasters and the upper zones the Chalk with Belemnites; but we did not systematically adopt these divisions as stages with definite names.

It was remarked (op. cit., p. 5) that "Our knowledge of the several faunas is not yet sufficiently complete to enable us to say precisely where a line could best be drawn between the two divisions or stages, and it is possible that some modifications of the zones will have to be made before two such stages can be established. Moreover, if such a division be found natural and desirable the existing nomenclature of the Chalk will have to be abandoned, for the formation will then be divided into four parts instead of three, so that the names Lower, Middle, and Upper could no longer be retained. The time has hardly yet arrived for this change to be made, but Mr. Hill and I wish to express our belief that it will come, and that some scheme of nomenclature more resembling that of the French geologists will have to be adopted for the Upper Cretaceous Series of England".

Nearly ten years have passed since the above was written, and the further researches which have been made since that time have only tended to strengthen our belief, but have at the same time shown the wisdom of waiting for more evidence before deciding where the line between the two divisions of the Upper Chalk should be drawn.

A more careful consideration of the question has convinced me that the distinction between these two portions of the Upper Chalk is less marked in England than it is in France or Germany. In England there is little variation in the lithological character of the deposit, which consists of nearly pure chalk throughout a thickness of some 1,100 feet. As a consequence the fauna has a similar facies throughout, and there is a complete passage from each zone to the next one, so that many species range from one into another. Moreover, all kinds of Cephalopoda except Belemnites are rare, so that it is impossible to use Ammonoids as zonal indices, and we are obliged to have recourse to Belemnites and Echinoderms.

On the other hand, in parts of France and Germany the pure chalk passes into other kinds of calcareous deposits, such as argillaceous marl, marly limestone, Bryozoan and siliceous limestones. Moreover, Ammonites are much less rare, and M. de Grossouvre has shown that a reliable zonal classification can be established on the recorded occurrences of the different species. There is also a greater number and greater variety of Echinoderms on the Continent than in England, so that the faunal difference between the one set of zones and the other is more apparent. Probably when the Brachiopoda have been more fully studied they also will show a more restricted range of species and varieties.

The cause of this more marked difference of fauna on the Continent is doubtless the fact that parts of the European region were land during most of the Cretaceous period, and that there was a greater variety of life in the shallower waters near the land-tracts than in the deeper water which lay over the British area and the greater part of the Paris Basin.

Before proceeding any farther it is necessary to make some remarks on the zonal division of the Upper Chalk. Until recently only six zones were recognized as its components in the South of England, but so long ago as 1899 and 1900 Mr. A. W. Rowe remarked that the true *Actinocamax quadratus* is so rare a fossil in England that *Offaster pilula* would be a better index fossil for the zone which has hitherto gone by the name of the former. At the same time he pointed out that *A. quadratus* only occurs in the higher part of the zone, the form found in the lower part being *A. granulatus*.

More recently Messrs. Griffith & Brydone have proposed to divide this zone, as developed in Hampshire,[1] into three sub-zones, viz.: (1) a sub-zone of *Echinocorys scutatus*, var. *depressa*, (2) a sub-zone of *O. pilula*, and (3) a sub-zone of *A. quadratus*. Mr. Brydone informs me, however, that he has since come to the conclusion that it will be better to make two distinct zones out of this great thickness of chalk, a lower zone of *O. pilula* and an upper one of *A. quadratus*. This proposal has the advantage of agreeing with the zonal divisions adopted in Germany, where this portion of the Chalk has been divided by Schlüter into a lower zone of *Scaphites binodosus* and a higher one of *A. quadratus*.[2]

In France also two zones have been recognized in this part of the Chalk; by J. Lambert in the Department of the Yonne, by A. Peron in the vicinity of Reims and Epernay, and in Aquitaine by Arnaud.

In the Yonne a series of zones was established by Lambert[3] and indicated by letters, his zone M being about 100 feet thick and corresponding with the *O. pilula* zone of Mr. Brydone, for it is characterized by the abundance of *O. pilula* with what is now known as *A. granulatus*. His zone N, about 130 feet thick, corresponds roughly with that of *A. quadratus*, its special fossils being *A. quadratus*, *Offaster corculum*, and *Micraster Schroderi* (=*M. glyphus* in Lambert's papers).

The same two zones can be recognized in the Marne near Reims where A. Peron[4] has shown that the 'craie à *A. quadratus*' is divisible into two zones, a lower one characterized by *Micraster gibbus*, var. *fastigatus*, Gauthier, and an upper one with *M. glyphus* (= *Schroderi*) and *Salenia Heberti*. *Offaster pilula* is also common in the lower zone and rare in the upper. In Aquitaine a similar succession of zones has been established by H. Arnaud,[5] and lettered in a similar manner from A to S. Of these the zone P^1 (= that of *O. pilula*) is characterized by the occurrence of *Micraster regularis*, *Echinocorys orbis*, and *Pyrina petrocoriensis*, and M. de Grossouvre has shown that its special Ammonite is *Placenticeras bidorsatum*. The zone P^2 (= that of *A. quadratus*) is a sandy chalk with few fossils except bands of *Ostrea vesicularis*, but examples of *A. quadratus* and *Mortoniceras delawarense* have been found in it.

From these observations it is clear that both in the South of England, the North of France, and in Aquitaine, the mass of chalk which lies between the zone of *Marsupites* and the Chalk containing *B. mucronata* is divisible into two distinct zones which are recognizable by the occurrence of certain species of Echinoderms and Belemnites, apart from the rarer occurrence of Ammonoids. Thus, if the zone of

[1] *The Zones of the Chalk in Hants*, by C. Griffith & R. M. Brydone (Dulau & Co., 1911), pp. 3, 10.

[2] See Schlüter in *Zeitsch. der Deutsch. Geol. Gesellschaft*, Bd. xxviii, p. 457, 1876, and Imp. Geol. Inst., Vienna, Sitz. for 1877.

[3] Lambert, "Terrain Crétacé du départ. de l'Yonne": Bull. Soc. Sci. hist. et nat. de l'Yonne for 1876.

[4] Peron, "Terrain de craie dans le Sud-est du bassin angloparisien": op. cit. *supra* (1887).

[5] "Le Terr. Crét. du Sud-ouest," Mém. Soc. géol. France (1877); and "Report of Excursion to the Charente", Bull. Soc. géol. France (1877).

Holaster planus be included in the Upper Chalk or Senonian there will be seven zones without reckoning that of *Ostrea lunata*.

In the following pages I shall endeavour to show that the Upper Chalk or Senonian of England, France, and Germany really contains two distinct faunas, and is consequently divisible into two stages as distinct as the Cenomanian and Turonian. I shall also consider the range of some of the component members of these faunas with the special object of determining the most natural line of division between these two stages.

French geologists long ago recognized the difference between the assemblages found in the lower and upper parts of d'Orbigny's Senonian stage, but they have never tabulated the fossils with the view of demonstrating the precise amount of this difference. They have divided the ancient 'Senonian' into two parts, and have given these parts definite names, but regard them as sub-stages and not as primary divisions of the series. German geologists have also recognized a division into Unter- and Ober-Senon, but they do not adopt the French names and they do not agree as to the horizon at which the plane of separation should be drawn.

To tabulate the whole Senonian fauna would be both a laborious and unnecessary task. If it really comprises two different assemblages, their diversity should be made apparent by a separate tabulation of two or three classes of organisms and especially by the Cephalopoda. This we shall find to be the case, but as Cephalopoda are not everywhere abundant I shall supplement their evidence by that of the Echinoids and the species of the genus *Inoceramus*.

Further, in order that the tabulated lists may be readily compared with one another the zones of the Senonian in England, France, and Germany must be correlated with one another, and as the zonal nomenclature has not yet been unified and perhaps cannot ever be made the same for all three countries, I have prepared a table of equivalent zones for reference.

The French and English zones are easily correlated because we have practically adopted the French zones, but in Germany the case is different. In the latter country the beds which contain typical *Micraster cortestudinarium* are known as the 'Cuvieri-planer' from the abundance of *Inoceramus Cuvieri*, and are placed at the top of the Turonian stage. This zone is overlain by a great thickness of grey marl and marly clay in which there are few Echinoderms, but a large number of *Inocerami* and Cephalopoda, the species indicating that these beds represent our zone of *Micraster coranguinum* with perhaps some of the underlying zone of *M. cortestudinarium*. These marls have been called the 'Emschermergel' from their development near Ems, and Dr. Schlüter regarded them as forming a separate stage between the Turonian and Senonian, but others more correctly consider the special character of the fauna as due to special local conditions of deposition.

The 'Emscher' Beds are succeeded by a set of sandy marls which Schlüter classed as Unter-Senon and divided into three zones, with the indices of (1) *Marsupites ornatus*, (2) *Pecten muricatus*, and (3) *Scaphites binodosus*. The two higher zones correspond with that of *O. pilula* in the Anglo-Parisian region, but in Germany this Echinid is only found in the overlying zone of *A. quadratus*, so that it cannot be used as an index, and *Scaphites binodosus* may be adopted instead. *A. granulatus* ranges throughout these marls, which are often called the 'granulaten-kalk'.

The Ober-Senon of Schlüter, i.e. the zones of *A. quadratus* and *B. mucronata*, corresponds with the rest of the English Upper Chalk. The equivalence of these zones is shown in the following table, in which I have also inserted the Ammonite zones established by de Grossouvre as an international basis of comparison:—

England.	France.	Germany.	Ammonite Zones.
B. mucronata.	*B. mucronata.*	*B. mucronata.*	*Pachydiscus neubergicus.* *Hoplites Vari.*
A. quadratus.	*A. quadratus.*	*A. quadratus.*	*Mortoniceras delawarense.*
Offaster pilula.	*Offaster pilula.*	*S. binodosus.*	*Placenticeras bidorsatum.*
Marsupites.	*Marsupites.*	*Marsupites.*	*P. syrtale.*
M. coranguinum.	*M. coranguinum.*	*Emscher marls.*	*Mortoniceras texanum.* *M. emscheris.*
M. cortestudinarium.	*M. decipiens.*	*I. Cuvieri.*	*Barroisiceras Haberfellneri.*

The reader will now be able to understand the zonal arrangements employed in the following tables and to appreciate the evidence thus presented. It will be convenient to begin with that of the Cephalopoda, and the first table shows the distribution of these fossils in the North of Germany, where they are more abundant than in England or France. This table has been compiled from that given by M. de Grossouvre in 1902[1] with the correction of a few misprints and mistakes:—

TABLE I.

Cephalopoda of the Upper Chalk in North Germany.

Species.	*Cuvieri* zone.	The *Emscher.*	Zone of *Marsupites.*	Zone of *S. binodosus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Mortoniceras Emscheris, Schlüter	-	x	-	-	-	-
M. pseudotexanum, de Gross.	-	x	-	-	-	-
Gauthiericeras Margæ, Schlüter	-	x	-	-	-	-
Peroniceras subtricarinatum, d'Orb.	x	x	-	-	-	-
P. Moureti, de Gross.	-	x	-	-	-	-
P. westphalicum, Stromb.	-	x	-	-	-	-
P. tridorsatum, Schlüter	-	x	-	-	-	-
Barroisiceras Haberfellneri, v. Hauer	-	x	-	-	-	-
Muniericeras clypeale, Schlüter	-	-	x	-	-	-
Placenticeras syrtale, Morton	-	-	x	-	-	-
P. bidorsatum, Römer	-	-	-	x	-	-
Puzosia Mulleri, de Gross.	x	-	-	-	-	-
Desmoceras patagiosum, Schlüter	-	-	-	-	-	x
D. obscurum, Schlüter	-	-	-	x	x	-

[1] "Recherches sur la Craie Supérieur": Mém. Carte Dét. de la France, fasc. ii, p. 790.

Species.	*Cuvieri* zone.	The *Emscher.*	Zone of *Marsupites.*	Zone of *S. binodosus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Sonneratia Daubréei, de Gross. . .	-	x	-	-	-	-
Hoplites falcatus (?), Mant.	-	-	-	-	-	x
H. cæsfeldensis, Schlüter	-	-	-	-	-	x
H. Vari, Schlüter	-	-	-	-	-	x
H. costulosus, Schlüter	-	-	-	-	-	x
H. lemfordensis, Schlüter	-	-	-	-	-	x
H. dolbergensis, Schlüter	-	-	-	-	-	x
Hauericeras pseudo-Gardeni, Schlüter	-	-	-	x	-	-
Pachydiscus peramplus, Mant. . .	x	-	-	-	-	-
P. dulmenensis, Schlüter	-	-	-	x	-	-
P. lettensis, Schlüter	-	-	-	-	x	-
P. Stobæi, Nilsson	-	-	-	-	x	x
P. gallicianus, Schlüter	-	-	-	-	-	x
P. icenicus (?), Sharpe	-	-	-	-	-	x
P. Portlocki, Sharpe	-	-	-	-	-	x
P. Koeneni, de Gross.	-	-	-	-	-	x
P. auritocostatus, Schlüter	-	-	-	-	-	x
P. haldemensis, Schlüter	-	-	-	-	-	x
P. neubergicus, Schlüter	-	-	-	-	-	x
P. Wittekindi, Schlüter	-	-	-	-	-	x
Gaudryiceras lunebergense, Schlüter .	-	-	-	-	-	x
Phylloceras velledæformis, Schlüter .	-	-	-	-	-	x
Scaphites Geinitzi, d'Orb.	x	-	-	-	-	-
S. aquisgranensis, Schlüter	-	-	-	x	-	-
S. binodosus, Römer	-	-	-	x	-	-
S. inflatus, Römer	-	-	-	x	-	-
S. hippocrepis, Dekay	-	-	-	x	x	-
S. gibbus, Schlüter	-	-	-	-	-	x
S. spiniger, Schlüter	-	-	-	-	-	x
S. constrictus, Sow.	-	-	-	-	-	x
S. ornatus, Römer	-	-	-	-	-	x
S. Reussi, d'Orb.	-	-	-	-	-	x
S. Roemeri, d'Orb.	-	-	-	-	-	x
S. pulcherrimus, Römer	-	-	-	-	-	x
S. tridens, Kner	-	-	-	-	-	x
S. nodifer (?), Hagenow	-	-	-	-	-	x
Ancyloceras Cuvieri, Schlüter . . .	x	x	-	-	-	-
A. padebornensis, Schlüter	x	x	-	-	-	-
A. retrorsum, Schlüter	-	-	-	-	x	x
A. pseudo-armatum, Schlüter . . .	-	-	-	-	-	x
Crioceras cingulatum, Schlüter . .	-	-	-	x	-	-
Toxoceras turonense, Schlüter . . .	x	-	-	-	-	-
Hamites Berkelis, Schlüter	-	-	-	-	-	x
H. recticostatus, Schlüter	-	-	-	-	-	x
H. cylindraceus, Defr.	-	-	-	-	-	x
Turrilites tridens, Schlüter	-	x	-	-	-	-
T. plicatus, d'Orb.	-	x	-	-	-	-
T. varians, Schlüter	-	x	-	-	-	-
T. undosus, Schlüter	-	x	-	-	-	-
Heteroceras polyplocum, Schloth. . .	-	-	-	-	-	x
Helicoceras reflexum, Quendst. . .	x	-	-	-	-	-
H. flexuosum, Schloth.	x	-	-	-	-	-

Species.	*Cuvieri* zone.	The *Emscher.*	Zone of *Marsupites.*	Zone of *S. binodosus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Baculites brevicosta, Schlüter	-	x	-	-	-	-
B. bohemicus, Fritsch	x	-	-	-	-	-
B. incurvatus, Dujard	-	x	x	x	-	-
B. anceps, Lam.	-	-	-	-	-	x
B. Knorri, Desor	-	-	-	-	-	x
Nautilus liotropis, Schlüter	-	x	-	-	-	-
N. neubergicus, Redtenb.	-	x	-	-	-	-
N. westphalicus, Schlüter	-	-	-	x	-	-
N. patens, Kner	-	-	-	-	-	x
N. altenensis, Schlüter	-	-	-	-	-	x
N. darupensis, Schlüter	-	-	-	-	-	x
N. loricatus, Schlüter	-	-	-	-	-	x
N. vaalsiensis, Binkh.	-	-	-	-	-	x
Actinocamax pederbornensis, Schlüter	x	-	-	-	-	-
A. westfalicus, Schlüter	-	x	-	-	-	-
A. verus, Müller	-	x	x	x	-	-
A. granulatus, Blainv.	-	-	x	x	-	-
A. Grossouvrei, Janet	-	-	x	x	-	-
A. Toucasi, Janet	-	-	x	x	-	-
A. mammillatus, Nilsson	-	-	-	-	x	-
A. quadratus, Blainv.	-	-	-	-	x	-
Belemnitella mucronata, Schloth.	-	-	-	-	x	x

From this table it will be seen that in Germany there are two very distinct assemblages of Cephalopoda; the one set being almost entirely restricted to the four lower zones, and the other set to the *quadratus* and *mucronata* zones. The one fauna comprises forty-seven species and the other forty-six species, of which only two are common to both, these two being *Desmoceras obscurum* and *Scaphites hippocrepis*. All the commoner and characteristic species of each fauna are absolutely restricted to it.

The passage zone of *S. binodosus* has yielded fifteen species, of which eight are peculiar to it, two range up into the *quadratus* zone, and five range down into lower zones. It will be seen in the sequel that the evidence of the *Inocerami* confirms the inference that this zone is more closely allied to the zone below than to the one above. Hence Dr. Schlüter seems to have been fully justified in drawing the line between his Unter- and Ober-Senon at the base of the *quadratus* chalk.

We will now pass to Belgium and the North of France, where a fair number of Cephalopoda have been obtained, though far fewer than in Germany. The following table shows the range of those which have been recorded from Belgium, the Cotentin, and Touraine, as well as from the Paris Basin proper; but it will be seen that few species are yet known to occur in the zones of *A. granulatus* and *A. quadratus*. In the Paris Basin these zones have not yet been specially examined and searched, except in the neighbourhood of Sens and of Reims; a few remains of Ammonoids have been found near Sens, but they are so imperfect that de Grossouvre was not able to identify them. No doubt better specimens will be obtained in course of time, and then the evidence will probably tend to coincide more closely with that of the German distribution of species.

In this table the letter F stands for France and B for Belgium.

TABLE II.

CEPHALOPODA IN BELGIUM AND THE NORTH OF FRANCE.

SPECIES.	Zone of *M. decipiens.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Tissotia Ewaldi, de Buch.	F.	-	-	-	-	-
T. haplophylla, Redtenb.	F.	-	-	-	-	-
Barroisiceras Haberfellneri, v. Hauer	F.	-	-	-	-	-
Mortoniceras Bontanti, de Gross.	-	F.	-	-	-	-
M. Bourgeoisi, d'Orb.	-	F.	-	-	-	-
M. Emscheris, Schlüter	-	F.	-	-	-	-
M. Zeilleri, de Gross.	F.	-	-	-	-	-
Gautiericeras Margæ, Schlüter	F.	-	-	-	-	-
G. bijuvaricum, Redtenb.	F.	-	-	-	-	-
Peroniceras Moureti, de Gross.	F.	-	-	-	-	-
P. subtricarinatum, d'Orb.	F.	-	-	-	-	-
P. tridorsatum, Schlüter	F.	-	-	-	-	-
P. westfalicum, Schlüter	F.	-	-	-	-	-
Hoplites Lafresnayi, d'Orb.	-	-	-	-	-	F.
Desmoceras ponsianum, de Gross.	F.	-	-	-	-	-
D. Stobæi, Nilsson	-	-	-	-	-	B.
Sphenodiscus Ubaghsi, de Gross.	-	-	-	-	-	B.
Placenticeras Fritschi, de Gross.	F.	-	-	-	-	-
P. syrtale, Morton	-	-	F.	-	-	-
Sonneratia Janeti, de Gross.	F.	-	-	-	-	-
Pachydiscus peramplus, Mant.	F.	-	-	-	-	-
P. telinga, Stoliczka	F.	-	-	-	-	-
P. leptophyllus, Sharpe	-	-	F.	-	-	-
P. colligatus, Binkh.	-	-	-	-	-	F., B.
P. gollevillensis, d'Orb.	-	-	-	-	-	F.
P. neubergicus, Schlüter	-	-	-	-	-	F., B.
P. inopinus, Hébert	-	-	-	-	-	F.
P. parisiensis, Hébert	-	-	-	-	-	F.
Scaphites Lamberti, de Gross.	F.	-	-	-	-	-
S. Meslei, de Gross.	F.	-	-	-	-	-
S. Potieri, de Gross.	F.	-	-	-	-	-
S. constrictus, Sow.	-	-	-	-	F.	F., B.
S. spiniger, Schlüter	-	-	-	-	-	F.
S. Verneuilli, d'Orb.	-	-	-	-	-	F.
S. tridens, Kner	-	-	-	-	-	B.
S. aquisgranensis, Schlüter	-	-	-	F., B.	-	-
S. hippocrepis, Morton	-	-	-	B.	-	-
Ancyloceras Douvillei, de Gross.	-	F.	-	-	-	-
Hamites cylindraceus, Defr.	-	-	-	-	-	F., B.
H. carolinus, d'Orb.	-	-	-	-	F.	-
Baculites anceps, Lam.	-	-	-	-	-	F., B.
B. incurvatus, Dujard.	-	-	F.	B.	-	-
B. Faujasi, Sow.	-	-	-	-	-	B.

Species.	Zone of *M. decipiens.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Nautilus Dekayi, Morton	-	-	F.	-	-	-
N. Heberti, Binkh.	-	-	-	-	-	F., B.
N. Le Hardyi, Binkh.	-	-	-	-	-	B.
N. vaalsiensis, Binkh.	-	-	-	-	-	B.
Actinocamax verus, Müller	-	-	F.	-	-	-
A. Grossouvrei, Janet	-	-	F.	-	-	-
A. westfalicus, Schlüter	F.	F.	F.	B.	-	-
A. granulatus, Blainv.	-	-	-	F., B.	-	-
A. quadratus, Blainv.	-	-	-	-	F., B.	-
A. Alfridi, Janet	-	-	-	-	F.	-
Belemnitella mucronata, Schloth.	-	-	-	-	F., B.	F., B.

No definite conclusions can be based on the above list, because so few species of Cephalopoda have yet been found in the zones of *O. pilula* and *A. quadratus*; but so far as the evidence goes it confirms that of the German Cephalopoda, for not one of the species occurring in the four lower zones ranges up into the higher. The zone of *B. mucronata* comprises nineteen species, and this fauna is completely different from that of the beds below the *quadratus* zone.

I have also tabulated the distribution of the Cephalopoda which occur in the corresponding zones of the South of France, Ammonoids being fairly numerous in some areas, especially in the Charentes, the Bordelais, and the Pyrenees. The deposits of Southern France differ so much from those of the northern area that the same zonal terminology is not applicable. Coquand, however, established a number of sub-stages which have again been subdivided by Arnaud, the result being a series of 'assises' which are practically zones. From the tabular view of these divisions and their principal fossils which has been given by de Grossouvre (op. cit., p. 383, table xiv) it is easy to correlate Arnaud's lettered zones with those of the Paris Basin, and from this source I have compiled a separate table of the Senonian Cephalopoda.

To print this table would unduly increase the length of this essay, but I may state some of the facts which are thus brought out. The most important fact is the obvious existence of two different faunas, the four lower zones having yielded no fewer than fifty-three species of Cephalopoda, and not a single one of them ranges into the two higher zones (i.e. of *A. quadratus* and *B. mucronata*), although these have jointly produced twenty-eight species. From the zone of *Placenticeras bidorsatum*, the equivalent of our *O. pilula* zone, eleven species have been obtained of which three are restricted to it, while all the rest range down into the zone below (that of *Placenticeras syrtale*), and none of them range upwards. Here, therefore, the plane of division between the two stages is clearly marked.

England is considered last because so few species of Cephalopoda have yet been found in our 'Upper Chalk', but so far as their evidence goes it confirms that of France and Germany. In the following table the separate records for the zones of *O. pilula* and *A. quadratus* are based on those given by Messrs. Griffith & Brydone, and on the fact that the highest beds in the Yorkshire cliffs belong to the former zone, though true *A. quadratus* has recently been found by Mr. Stather near Bridlington.

TABLE III.

CEPHALOPODA OF THE UPPER CHALK IN ENGLAND.

SPECIES.	Zone of *M. cortestudinarium.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Pachydiscus leptophyllus, Sharpe	-	x	x	x	x	-
P. Portlocki, Sharpe	-	-	-	-	-	x
P. icenicus, Sharpe	-	-	-	-	-	x
P. Oldhami, Sharpe	-	-	-	-	-	x
Hauericeras pseudo-Gardeni, Schlüter	-	-	-	x	-	-
Haploceras sp. (aff. *catinus*)	-	-	-	-	-	x
H. obscurum, Schlüter	-	-	x	-	-	-
Lytoceras Jukesi, Sharpe	-	-	-	-	x	x
Phylloceras velledæformis, Schlüter	-	-	-	-	-	x
Hamites cylindraceus, Defr.	-	-	-	-	-	x
Heteroceras polyplocum, Schloth.	-	-	-	-	-	x
Scaphites binodosus, Römer	-	-	-	x	-	-
S. inflatus, Römer	-	-	-	x	-	-
Baculites Faujasi, Sow.	-	-	-	-	-	x
Nautilus Bayfieldi, F. & C.	-	-	-	-	-	x
N. cf. *atlas*, Whit.	x	-	-	-	-	-
N. darupensis, Schlüter	-	-	-	x	-	-
Actinocamax granulatus, Blainv.	-	x	x	x	-	-
A. verus, Müller	-	x	x	x	-	-
A. westfalicus, Schlüter	-	x	-	-	-	-
A. Toucasi, Janet	-	-	-	x	-	-
A. quadratus, Blainv.	-	-	-	x	x	-
Belemnitella mucronata, Schloth.	-	-	-	-	-	x
B. lanceolata, Schloth.	-	-	-	-	-	x

The total number of species enumerated above is twenty-four, of which twelve occur in the four lower zones and thirteen in the higher, the only Ammonoid which is ostensibly common to the two faunas being *Pachydiscus leptophyllus*; but there is no doubt that several species have been included under this name, and that when they have been differentiated one form will prove to be restricted to the lower zones. The only locality yet known where *A. quadratus* occurs in the zone of *O. pilula* is the Salisbury district, where it prevails, as Dr. Blackmore informs me, to the exclusion of *A. granulatus*.

(*To be concluded in our next Number.*)

VI.—The Younger Rock Series of New Zealand.

By Dr. P. Marshall, M.A., D.Sc., F.G.S., Professor of Geology and Mineralogy in the University of Otago, Dunedin, New Zealand.

In the December number of the Geological Magazine. 1911, pp. 539–49, appeared an article by Professor James Park, F.G.S., on the Lower Tertiaries and Upper Cretaceous of New Zealand. As the author indicates, this article is largely a criticism of a paper on the the Younger Rock Series of New Zealand, written by Mr. R. Speight, Lecturer on Geology, Canterbury College, Mr. C. A. Cotton, Lecturer on Geology, Victoria College, and myself. You will doubtless understand from this statement that with the exception of Professor Thomas,

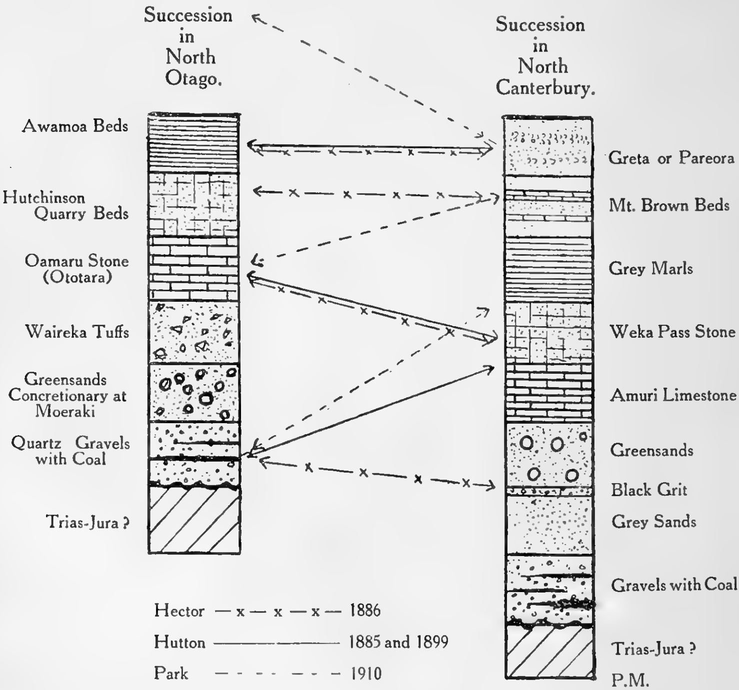


Fig. 1. Comparison of Correlations of Younger Rocks.

of Auckland, with whom we had no opportunity of collaborating, all of those who are at present engaged in teaching geology in the University of New Zealand are co-authors.

This paper was published in the Transactions of the New Zealand Institute, vol. xliii, p. 378, 1910. The great majority of your readers have, of course, not seen this paper, and are not aware of its main contention, nor of the arguments that were adduced in support of it. This is somewhat to be regretted, and I must therefore ask for your permission to restate the gist of these, and also to make

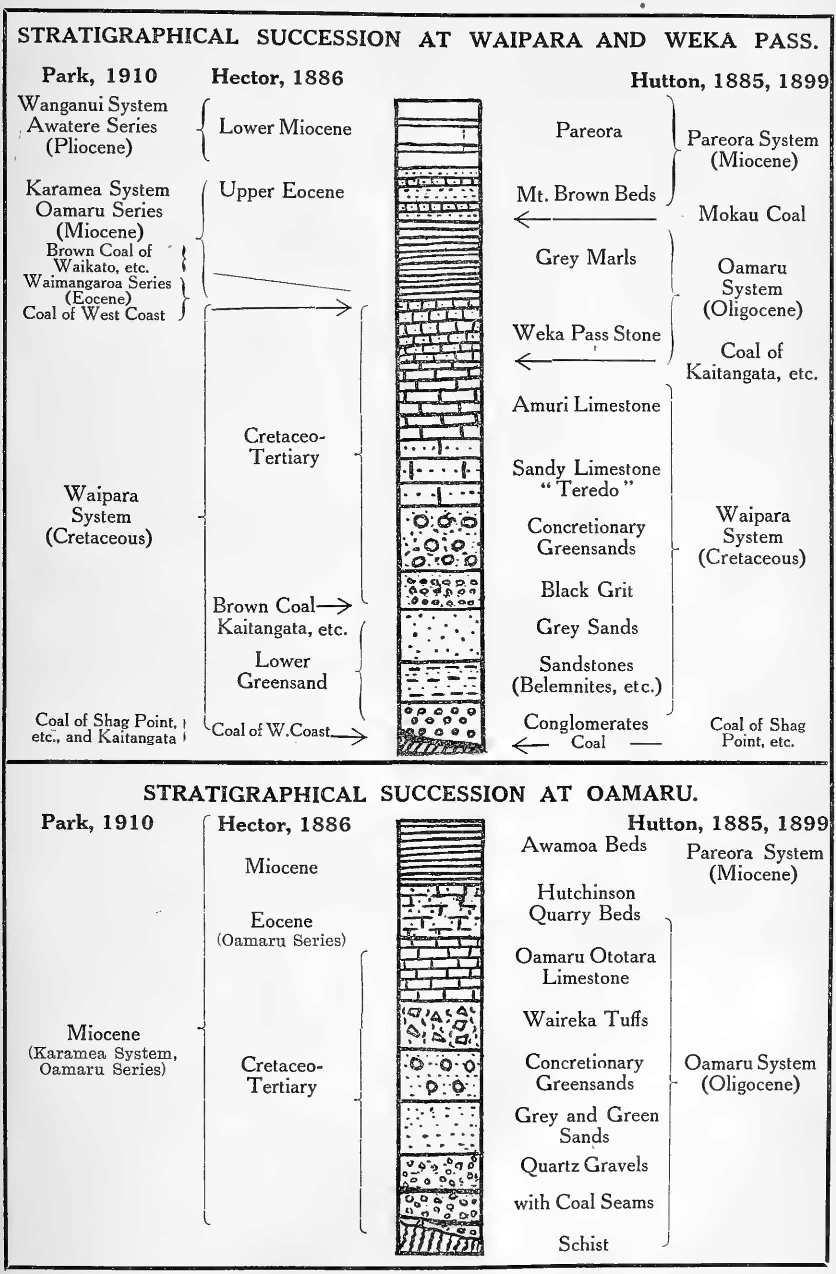


FIG. 2.—These tables (Figs. 1 and 2) are reproduced from the original paper by Marshall, Speight, & Cotton, "Younger Rock Series of New Zealand": Trans. New Zealand Institute, vol. xliii, p. 383, 1910.

further statements and explanations that will refute much of the criticism that appeared in the article referred to.

The history of the various classifications of these strata appears to me to be beside the point, and I shall not refer to it. I should wish to reproduce the two diagrams (see *ante*, Fig. 1, p. 314, and Fig. 2, p. 315), for no objections have been offered to them, and they appear to me to give a correct diagrammatic view of the various opinions that have been and still are held in regard to the stratigraphical position of these beds, and to the correlation of the members as developed in different parts of the country. If these diagrams produce no other impression, they will at least show clearly enough that a great variety of widely diverging views has been expressed in regard to them. Anyone who has not seen the strata in the field will naturally conclude that their arrangement must be highly involved and complex. This, however, is not the case in the most typical localities, for, as Professor Park has said in the most emphatic manner of the typical locality in the Waipara, "The sequence of the beds as just enumerated is the most complete to be found in any part of New Zealand. The stratigraphy is plain and simple, being free from obscurities and offering few points of possible disagreement." Again, "The strata at the Waipara where the complete sequence is exposed are quite undisturbed, following one another uniformly throughout all parts of the district. . . . I am strongly of the opinion that a complete sequence of beds exists from the base of the Cretaceo-Tertiary"—now the base of his Cretaceous—"to the close of the Pareora formation." [1]

Notwithstanding this opinion, with which we cordially agree, unconformities have been described by nearly all observers as occurring in various places in this series. The exact places at which these were described as distinct were visited by us, and the complete evidence of absolute conformity in every case appeared to us to be overwhelming. It is worthy of remark in passing that though Hector, Hutton, Haast, and Park have visited and described the same sections, they have in nearly every case stated that the unconformities described by the others are not present.

The authors of the paper criticized in your article visited the district in company, and in the paper describing our observations gave reasons for believing that the whole series was conformable. In particular, we showed that Professor Park had misread the structure on which his unconformity above the Weka Pass Stone was based, and also that upon which his separation of the Mount Brown and Motanau Beds was based. As regards the latter he at first asserted: "The section exposed in this cutting is of great importance, as here the Motanau Beds are seen to rest unconformably upon the Mount Brown Beds. The section is so clear that no doubt can be entertained as to the unconformable relations of the two formations." [2] In the *Geology of New Zealand* he states: "In the Waipara district the Greta Beds of the Awatere Series are resting unconformably on a highly denuded surface of the Oamaruian." [3] Apparently, however,

[1] Rep. Geol. Explor., 1887, pp. 28, 33.
[2] Trans. N.Z. Inst., vol. xxxvii, p. 538, 1904.
[3] *Geology of New Zealand*, 1910, p. 158.

he has accepted our explanation of the section, for he writes in your article: "The unconformity which I thought I recognized at Waipara between the Mount Brown and Motanau Beds may not exist, or if it does it may be purely local."[1] He offers no criticism of our explanation of the structure that he had described as an unconformity between the Weka Pass Stone and the Mount Brown Beds, and therefore admits the conformable nature of the stratigraphy as insisted upon by us. He does, however, still advocate a palæontological unconformity. "The Ototara Stone is everywhere fossiliferous generally, and its characteristic fossils from one end of New Zealand to the other are *Pseudamusium huttoni*, which is never known to be absent, *Cirsotrema browni*, and *Meoma crawfordi*. The Weka Pass Stone, on the other hand, has never yielded any recognizable fossils." Again, on p. 548, "Moreover, *Cirsotrema browni*, *Pseudamusium huttoni*, and *Meoma crawfordi* are characteristic of the Ototara horizon from one end of New Zealand to the other." On p. 541 the Weka Pass Stone is shown in his tabulated series as the highest member of his Cretaceous (Waipara) Series and the Ototara Stone as the highest member of his Lower Tertiary (Oamaru) Series.

These statements have been quoted here because quite recently Dr. J. A. Thomson and Mr. C. A. Cotton have found *Pseudamusium huttoni*, *Cirsotrema browni*, and Echinoderm remains not sufficiently well preserved for identification within the Weka Pass Stone not two feet from its base.

We thus have a very satisfactory palæontological proof that the Weka Pass Stone and the Ototara Stone are of similar age. Since, in the article referred to, the Waipara Series is represented as perfectly conformable below the Weka Pass Stone, and the Mount Brown and Motanau Beds perfectly conformable above the Weka Pass Stone, we find that this fortunate discovery of palæontological evidence brings Professor Park's position exactly to ours. We feel that it is most satisfactory to have this complete agreement on such a controversial and, to New Zealand geologists, most important matter. This discovery further allows of complete correlation between the Waipara Series and the Oamaru Series, called respectively Cretaceous and Lower Tertiary Series by Professor Park. The Weka Pass Stone is the highest member of the former, and the Ototara Stone is the highest member of the latter, and there is a remarkably similar lithological succession in the two series.

The Weka Pass Stone has been admitted by everyone but Hutton to be conformable to the Amuri Limestone below it. Park, for instance, says: "I carefully examined the line of contact of the two rocks, but was unable to find any evidence of unconformity."[2] McKay has been even more emphatic on this point.[3] The Amuri Limestone is a hardened chalk, formed mostly of broken tests of Globigerina; the Weka Pass Stone is an arenaceous limestone with much glauconite. There is much the same relation between the two rocks as between the Ototara Stone, which typically contains

[1] Geol. Mag., Dec. V, Vol. VIII, p. 548.
[2] Trans. N.Z. Inst., vol. xxxvii, p. 546, 1904.
[3] McKay, Rep. Geol. Explor. of N.Z., 1886–7, pp. 83–7.

no glauconite and very rarely any mollusca, but an abundance of Foraminifera, and the Hutchinson Quarry Beds, which are nothing more than calcareous greensands above the Ototara Stone. Since Professor Park admits conformity between the two beds at the Waipara and between the Ototara and Hutchinson Quarry Beds at Oamaru, and since its characteristic fossils are common to both, it is obvious that he cannot object to the correlation of the two series, Amuri Limestone with Ototara Stone; Weka Pass Stone with Hutchinson Quarry. This is the correlation which we have adopted, so there must be now substantial agreement on this point also.

Much insistence has been laid on these sections in North Canterbury, because they are perfectly clear and have been admitted as of crucial importance on all sides; Professor Park, for instance, says of it: "The sequence of beds just enumerated is the most complete to be found in any part of New Zealand, and for this reason the Waipara must for ever remain the typical locality for the study of the formations that they represent."[1]

Not only is there a complete conformity at Waipara, but also at the Weka Pass 10 miles away, at Amuri Bluff 70 miles distant to the north-east, and at Oamaru 200 miles to the south. I am perfectly willing to admit that two formations of different ages may locally show apparent conformity; but conformity at places so widely distant in such a similar rock succession cannot fail to convince any geologist that the formations are strictly conformable.

In your article of December, however, the ground is somewhat shifted; for Kaitangata, Shag Point, and Komiti Point are there taken as localities illustrating unconformable stratigraphical relations. Of the first of these it is only necessary to quote: "No actual contact of the Cretaceous rocks and Tertiaries is anywhere exposed."[2] Obviously this unconformity is a matter of inference, and the district is of no critical importance compared with the clear and continuous sections mentioned above.

At Shag Point it is stated in the article referred to that: "The Tertiary rocks form the low bank of a branch of the Shag River near the mouth, well within the influence of tidal flow." Beneath the diagram on p. 543 it reads: "Calcareous sandstone . . . as seen in the north bank of Shag River." Search failed to reveal these beds on the low banks of a branch of the river. They are, however, well known to occur on the south bank of the main river. This is half a mile away from the nearest exposure of the conglomerates of Puke iwi tahi, and the intervening ground shows no rock exposure, and its surface is covered with soil and pasture. On Puke iwi tahi itself the dip is 70 degrees east at the base, and 15 degrees east at the top. Four hundred yards from the top the beds when followed along the ridge have a strike that in this distance bends from north to north-west, that is, through an angle of 45 degrees. One and a half miles distant along the strike from the base of Puke iwi tahi the dip is 75 degrees west in Little Puke. A quarter of a mile to the east of

[1] Rep. Geol. Explor. of N.Z., 1887–8, p. 33.
[2] Geol. Mag., Dec. V, Vol. VIII, p. 544.

Puke iwi tahi the dip changes to the east, and shortly afterwards a complete pericline is developed.

Such changes in the dip and strike show that the rocks are much disturbed, and when the structure of rocks of similar age at Weka Pass is considered, it is reasonable to demand an actual junction to establish an unconformity instead of a difference in dip and strike of two rock exposures separated by half a mile of grass-covered country. This distance would allow of the intercalation of all the members of the rock series in their proper order; but even if a structural break be insisted on a fault offers a more reasonable explanation, as has been shown at length by Cox, Hector, and McKay. Northward from Shag Point along the coast, Hector states that no unconformity was discovered: "Thus completing the succession from the lowest" (conglomerates of Shag Point) "to all but the highest beds of the Cretaceo-Tertiary sequence."[1]

At Komiti Point no work has been done since 1886–7, when Professor Park reported on the district. He says: "At the point opposite Batley they" (Komiti Beds—Lower Miocene) "lie on the upturned edges of the chalky clays belonging to the Inoceramus Beds (certainly Jurassic, p. 229), and on the south side of the Otamatea, opposite Batley, they rest on the hydraulic limestone, but whether conformably or not I was unable to decide, as on account of the shattered and jointed condition of the limestone all trace of the original bedding is now obliterated. However . . . a certain amount of unconformity may be allowed at this point, but the lapse of time that this unconformity would represent must be very limited judging from the very close affinities that exist between the fauna of the Komiti Beds and that of the marly greensands underlying the hydraulic limestone at Pahi."[2] This is the section which twenty-six years later without further description is used to separate the New Zealand Cretaceous from the Miocene, and for the interpretation of the Waipara section 600 miles distant, which must "ever remain the typical section for the study of the formations that they represent".[3]

"The beautiful section near Wade" was not considered of sufficient importance for description when discovered, and has not been described since. It is not even mentioned in Park's *Geology of New Zealand*. However, all such sections are largely beside the point. It is in the district of North Canterbury that the younger series of rocks is most perfectly developed and displayed, and it is universally agreed that conclusions as to their relationships must be based on the perfect and continuous sections there exposed.

In conclusion, will you allow me to state most briefly the reasoned conclusions at which we arrived after a stratigraphical study of the younger rocks of New Zealand.

1. That there is a single rock series which consists of conglomerates, sandstones, greensands, limestone, greensands, grey marls, and brown sands, which is found in more or less complete development wherever the rocks are exposed. Necessarily in some places certain

[1] Rep. Geol. Explor. of N.Z., 1886–7; *Progress Report*, p. xx.
[2] Ibid., 1886–7, p. 228.
[3] Ibid., 1887–8, p. 33.

members may be contracted or even absent while others may be correspondingly expanded in accordance with local variations in the conditions under which their accumulation took place. For instance, the basal conglomerate is not more than 5 feet thick at Amuri Bluff, while at Shag Point the least thickness that has been assigned to it is 1,250 feet. South of Oamaru the grey marls are almost entirely absent, while in the Wanganui Basin they are at least 2,000 feet thick, and their deposition there extended throughout all later Tertiary time. In localities adjacent to the old shore-line greensands and limestones are practically absent.

2. The very nature of the rock succession indicates continuous, uniform, regional depression until after the deposition of the limestone. Thereafter elevation commenced.

3. As a result of this movement of a land surface previously much eroded, the upper strata that were deposited widely overlap those that were deposited earlier.

4. As the shore-line retreated the districts where the basal conglomerates were first deposited became deep-water areas, while conglomerates were still forming on the sea margin which in consequence of the depression had advanced far on to the old land surface. The conglomerates in their different portions therefore represent the various periods that elapsed during the progress of the movement of depression. This consideration seems to me to satisfactorily explain the association of faunas of different ages with the conglomerates. When these basal beds are well known it is reasonable to suppose that the complete development of the Tertiary fauna will be revealed.

5. The fact that conglomerates of different localities contain different faunas does not indicate that two series of rocks are present, but it is the necessary result of the accumulation of sediment on the margin of a gradually retreating shore-line.

6. The coal-seams are always found in the basal conglomerates and associated beds, and may therefore belong to any of the periods that elapsed during the movement of depression. Low-lying littoral districts were constantly being converted into swampy areas where vegetable matter would accumulate, and from this coal would afterwards be formed. Conditions favourable for the formation of coal might occasionally recur during elevation; but the vegetable matter would then not usually be buried, and all superficial deposits would be rapidly eroded.

I hope that this brief résumé sufficiently indicates the radical difference between our explanation and that based upon the Cretaceo-Tertiary classification with which there is a tendency in some minds to confuse it. The Cretaceo-Tertiary classification hypothecated three separate periods of deposition separated by periods of elevation. It placed practically all the coal-seams in the middle of these three periods and thus classed all of them as the same age. This latter idea has now been abundantly disproved.

I may say that although alone responsible for this reply to Professor Park's criticism, it has been submitted to Messrs. Speight and Cotton, and meets with their approval.

VII.—The Cirripede '*Brachylepas cretacea*', H. Woodward.

By Thomas H. Withers, F.G.S.

(PLATE XX.[1])

AMONG the fossil Cirripedia the species '*Brachylepas cretacea*' is of extreme interest, since it affords an important connecting link between the pedunculate and sessile forms. Records of its geographical distribution, moreover, show it to have an exceedingly wide range, but up to the present its vertical range appears to be restricted to the zone of *Belemnitella mucronata* in the Upper Senonian. We owe our knowledge of *Brachylepas* to Dr. H. Woodward, F.R.S., who in 1868 founded the species *B. cretacea* on a single valve under the genus *Pyrgoma*, and in 1901 on a further and more complete specimen established the genus *Brachylepas* and the family Brachylepadidæ. Attention is now drawn to this species mainly on account of the fortunate find of the remaining valves of the capitulum.

In a work on the fossils of the Chalk of Meudon, Ed. Hébert (1855) described and figured what now appears to be a valve of *Brachylepas cretacea*, under the name *Emarginula* (?) *Naissanti*. J. Boehm (1906) called attention to this figure, and considered that it was distinguished from *B. cretacea* only by its smaller size, and that, should further research show that in it we had a young stage of *B. cretacea*, then this form, so widely though sparsely distributed in the Baltic Chalk, would be denoted as *B. Naissanti*, Hébert, sp.

Before seeing Boehm's note I had already formed the opinion that the specimen figured by Hébert as *Emarginula* (?) *Naissanti* was the same species as *Brachylepas cretacea*, H. Woodward. In response to an application from the Geological Department of the British Museum, search for Hébert's type-specimen was most kindly made by the Director of the Muséum National d'Histoire Naturelle, Paris, by Professor Emil Haug of the Sorbonne, and Mr. Léon Bertrand of the École Normale, where most of Hébert's earlier type-specimens are preserved. The specimen, however, could not be found and, as Professor Haug writes, has probably been lost. Fortunately Hébert's figure is quite good and readily recognizable. Moreover, it is so like the figure of *Pollicipes cancellatus* given by Marsson (1880), which Dr. H. Woodward (1906, p. 338) said was undoubtedly the same as his *B. cretacea*, that they might even serve for figures of the same specimen; and the identity of the two latter species is fully borne out by an examination of their type material. The three type-specimens therefore must be referred to a single species under the name *B. Naissanti*, Hébert, sp.

History.—The earliest record of this species appears to be that given by Nilsson (1827) who figured a valve from the Chalk of Scania as "maxilla inferior . . . *Belemnitæ mammillati*". This opinion was held because these valves were found always in association with *Belemnites mammillatus* (= *B. subventricosus*).

Ed. Hébert (1855) thinking that a valve found in the Chalk of Meudon was a portion of an Emarginuloid shell, described and figured it as *Emarginula* (?) *Naissanti*.

[1] Plate XX will appear with the second part of this paper in August.

H. Woodward (1865) called attention to a valve from the Chalk of Norwich, which he considered to be a portion of the shell of a sessile Cirripede belonging to the genus *Pyrgoma*, and for which he proposed the name *P. cretacea*. This valve, discovered by the late T. G. Bayfield, of Norwich, was subsequently fully described and figured by Dr. H. Woodward in 1868.

J. I. Lahusen (1873) described and figured as beaks of a *Nautilus*, two valves, a carina, and rostrum, from the White Chalk of Simbirsk, Russia. He figured also, as *Pollicipes* sp., some valves associated on the same piece of chalk, consisting of a nearly complete scutum, and what appear to be portions of two terga.

Th. Marsson (1880) described and figured under the name *Pollicipes cancellatus* a valve of this Cirripede, which he said was not uncommon in the Chalk of Rügen, is easily recognizable, and not to be confused with any other Cirripede. He described and figured the carina only, but mentioned that he had recognized parts of latera, and probably an upper latus, and part of a tergum. These, however, were said to be too incomplete to permit of the reconstruction of the form of the valves.

W. Dames (1881) in a review of Marsson's paper, said that valves of *P. cancellatus* were not uncommon in the Chalk of Lüneburg, and had also been described by J. I. Lahusen (1873) as beaks of a *Nautilus*, from the White Chalk of Simbirsk, Russia.

F. A. Quenstedt (1883) figured a valve, probably a rostrum, and said that smooth and very broad carinal valves occurred in the White Chalk of Lüneburg, and that these might appropriately be named *Pollicipes lævissimus*.

K. A. Zittel (1885) in his *Handbuch der Palaeontologie*, figured a series of valves from the Upper Chalk of Lüneburg without description under the name *P. lævissimus*, Quenstedt. These valves are respectively called "carina, ? rostrum, scutum, tergum, and lower latera". There are three lower latera, but no upper latus.

H. Woodward (1901) in a further paper on '*Pyrgoma cretacea*' added much to our knowledge of this species, through the discovery by Dr. A. W. Rowe of a remarkable specimen from the *Belemnitella mucronata*-zone of Norwich. This fossil consisted of the carina and rostrum, which were kept in position through the presence of three or four whorls of imbricating plates round the base of the capitulum. From a study of this new specimen of '*Pyrgoma cretacea*', Dr. Woodward concluded that it would have to be removed from the genus *Pyrgoma*, and he based on it the genus *Brachylepas* and the family Brachylepadidæ. He remarked on the absence of the remaining valves, but did not refer to the valves already figured by Zittel (1885). He thought also that scuta, terga, and perhaps a small and narrow latus, completed the capitulum, and he represented these valves diagrammatically in a restoration.

A. Wolleman (1902) noticed some valves from the *Belemnitella mucronata*-zone of Lüneburg, and referred them to *Pollicipes cancellatus*, Marsson. He suggested also that the valves figured by Zittel (1885) as *P. lævissimus* were probably worn valves of *P. cancellatus*.

H. Woodward (1906) remarking on a specimen of *Brachylepas cretacea*, collected by Mr. R. M. Brydone in the Chalk of Trimingham, said: "A careful comparison of Mr. Brydone's specimen with Dr. Marsson's figure on the one hand and with the long series of specimens obtained by Dr. Rowe from the Chalk of Catton, near Norwich, leaves no doubt in my mind that *Pollicipes cancellatus*, Marsson, is identical with *Brachylepas* (*Pyrgoma*) *cretacea*, H. Woodward, 1868, so that *Pollicipes cancellatus* must be treated as a synonym of *Brachylepas cretacea*."

J. Boehm (1906) called attention to a shell-fragment from the Upper Senonian of Haldem, preserved in the Geologisches Landesmuseum of Berlin, and said that it agreed exactly in form and sculpture with H. Woodward's figure of *Brachylepas cretacea* (1901, Pl. VIII, Fig. 4), except that the ribs were thinner and sharper, just as they were in Fig. 4*a*. He said also that the fossil described by Hébert (1855) as *Emarginula* (?) *Naissanti* was distinguished from the preceding only by its smaller size, and that if it should be found to be a young stage of *B. cretacea*, then this form would have to be known as *B. Naissanti*, Hébert, sp.

Distribution of *Brachylepas Naissanti*. Upper Senonian, zone of *Belemnitella mucronata*: Catton, near Norwich, Norfolk; Edward's Pit, Mousehold, near Norwich, Norfolk; Weybourne and Trimingham, Norfolk; Whitway Farm Pit, South Dorset; Isle of Wight; Meudon, France; Isle of Rügen; Haldem, Westphalia; Lüneburg, Hanover; Scania, Sweden; Simbirsk, Russia.

BRACHYLEPAS NAISSANTI, Hébert, sp. (Plate XX.[1])

1827. *Belemnites mammillatus* (maxilla inferior), S. Nilsson, Petrificata Suecana, pp. 9, 10, pl. ii, figs. 2D.
1855. *Emarginula* (?) *Naissanti*, Ed. Hébert, Mém. Soc. géol. France, 2^{e} sér., vol. v, p. 374, pl. xxix, fig. 10.
1866. *Pyrgoma cretacea*, H. Woodward, Rep. Brit. Assoc. (1865), p. 321.
1868. *P. cretacea*, Woodward: H. Woodward, GEOL. MAG., Dec. I, Vol. V, p. 258, Pl. XIV, Figs. 1, 2, 2*a*.
1873. *Nautilus* sp. (beaks of), J. I. Lahusen, Fossils of the White Chalk of Simbirsk; Jubilee Volume of the Imperial Russian Mining-Corps Institute, pt. ii, p. 264, pl. vi, figs. 8, 9.
1873. *Pollicipes* sp., J. I. Lahusen, op. cit., p. 270, pl. vi, figs. 15*a*, *b*.
1877. *Pyrgoma cretacea*, Woodward: H. Woodward, Brit. Mus. Cat. Brit. Foss. Crustacea, p. 141.
1880. *Pollicipes cancellatus*, Th. Marsson, Cirrip. d. Weiss. Schrieb.-Kreide d. Rügen, p. 24, pl. ii, fig. 7.
1880. ?*P. fallax*, Darwin: Th. Marsson, op. cit., p. 22, pl. ii, fig. 6.
1881. *P. cancellatus*, Marsson: W. Dames, Neues Jahrb., Bd. ii, p. 419.
1883. *P. lævissimus*, F. A. Quenstedt, Handb. der Petrefaktenkunde, Abth. ii, p. 467, pl. 37, fig. 13.
1885. *P. lævissimus*, Quenstedt: K. A. Zittel, Handb. der Palaeontologie, Bd. i, Abth. ii, p. 534, fig. 723.
1901. *Brachylepas cretacea*, Woodward, sp.: H. Woodward, GEOL. MAG., Dec. IV, Vol. VIII, p. 150, Pl. VIII, Figs. 3, 4*a*, *b*, pp. 240, 528.
1902. *Pollicipes cancellatus*, Marsson: A. Wolleman, Abh. k. preuss. geol. Landesanst., N.F., Hft. xxxvii, p. 114.
1906. *Brachylepas cretacea*, Woodward, sp.: H. Woodward, GEOL. MAG., Dec. V, Vol. III, p. 337.
1906. *B. cretacea*, Woodward, sp.: J. Boehm, Centralbl. f. Min., p. 449.

Some time ago I was able to obtain a carina, now referred to *Brachylepas Naissanti*, embedded in a piece of bluish-grey marly chalk, said to have come from the "chalk with *Belemnites mucronatus* at Lüneburg, Hanover". To see certain points of structure it was necessary that the inner surface of the valve should be exposed, and the valve was consequently removed from its matrix. When on the point of throwing the matrix away, it was thought, since it was very marly, that it would be easy to wash for Foraminifera. After soaking the chalk, the dirty water was poured off, and to my astonishment a large number of Cirripede valves appeared. Indeed, it seemed impossible that such a small piece of chalk could have completely hidden them. The valves consisted of three nearly perfect carinæ with several fragments, two nearly perfect rostra with portions of others, nine scuta, thirteen terga, five upper latera, all more or less perfect, and about 120 valves of the lower whorls. It is quite possible that had the presence of further valves in the matrix been suspected at first, at least one more or less complete capitulum could have been obtained. This is not at all unlikely, since it was possible

[1] Plate XX will appear in the August Number.

to save some of the lower latera which were still held together by the matrix even after soaking. These valves undoubtedly represent a colony of individuals the remains of which were embedded together, and proof of this is afforded by the fact that the carinæ, rostra, scuta, terga, and upper latera include quite young valves measuring about 2 mm. in size, the others ranging up to as much as 12·5 mm. Moreover, not a single valve of any other species of Cirripede was found with them.

Of the English representatives of *Brachylepas Naissanti*, the carina, rostrum, and lower latera only have been described, these valves being represented in position in the remarkable specimen in the collection of Dr. A. W. Rowe from the *B. mucronata*-zone of Norwich. As already stated in the History (see p. 322), Zittel (1885) figured detached examples of all the valves of this form from the Chalk of Lüneburg, with the exception of the upper latera, under the name *Pollicipes lævissimus*, Quenstedt. Unfortunately he gave no description of them, neither does he say whether they were found separately or associated. In these circumstances, and since these newly found valves complete our knowledge of the capitulum of *Brachylepas Naissanti*, it is here proposed to give descriptions of the several valves, and to discuss what further light they throw on this interesting form.

Carina (Fig. 1) semi-conical, inner margin straight or bowed outwards;[1] apex acute; basal margin semicircular, somewhat concave. Inner surface thickened near the lateral margins, this portion being marked with fine growth-lines, which are continued under the apex to about one-sixth the extent of the valve; these growth-lines indicate the extent to which the valve projected freely. External surface marked with several feebly marked ridges radiating from the apex; these are more pronounced near the apex and die out towards the basal margin. These ridges are crossed by feebly swollen bands, parallel to the basal margin, giving a cancellated appearance to the valve, especially near the apex where the ridges are much sharper. The ends of the transverse ridges give a serrated appearance to the lateral margins.

Rostrum (Fig. 2) semiconical, smaller and proportionally broader than the carina, inner margin straight or bowed outwards. Inner surface thickened near the lateral margins, and marked by growth-lines, which are continued under the apex to about half the length of the valve; the free projection of this valve therefore was proportionally much greater than that of the carina. Outer surface ornamented as in the carina, but more pronounced; and the ridges radiating from the apex, especially in young specimens, give the basal margin a toothed appearance.

Scutum (Fig. 3) almost triangular; occludent margin convex and in its upper part bowed towards the terga; basal margin slightly concave; tergal margin in its upper part slightly concave, and its lower part slightly convex; apex and basi-lateral angle acute. Ad-occludent portion moderately convex transversely, and on reaching a line from the apex to the basi-lateral angle, rising up to form a fold or ridge which on the tergal side is sharply folded downwards and inwards, from which the tergal portion is abruptly deflected. Parallel with the occludent margin, a narrow slip of the valve is bent downwards and forms an indistinct ridge on the upper surface, on which the growth-lines are directed upwards towards the apex. Inner occludent edge thickened, flat, narrow, and marked by lines of growth; a slight ridge runs obliquely from the tergal margin

[1] The carina and rostrum of this Cirripede are either straight or outwardly bowed, a feature that I have observed in certain fossil and recent species of *Pollicipes*. It does not appear to be of specific importance. A rostrum of this species from the Chalk of Norwich in the British Museum (Natural History), registered I. 14028, is considerably bowed outwards.

just below the pit for the adductor muscle, and meets the ridge formed by the inner occludent margin just above the pit, thus forming an obtusely angular depression (marked by lines of growth) for the reception of the tergo-lateral angle of the tergum. External surface marked by somewhat irregular, feeble transverse ridges, which appear to become more regular and prominent in the larger valves.

Tergum (Fig. 5) sub-rhomboidal, divided into almost equal portions by a prominent ridge curving from the apex to the basal angle, formed by the valve being sharply bent along this line; apex pointed and curved towards the scuta; lower part of valve narrow and pointed; upper carinal margin generally considerably convex, and usually shorter than the lower carinal margin; occludent margin shorter than the scutal margin. A portion of the valve along the occludent margin is rounded and protuberant, and is bounded by a depression running from the apex to the scutal margin at a point about one-fourth the distance from the occludent margin, to which extent the valve was overlapped by the scuta; a further indistinct fold or ridge runs from the apex to about the middle of the scutal margin. Valve externally marked with transverse ridges like the scutum, forming an acute angle on the central ridge. Inner surface of upper carinal margin thickened to a very small extent and marked by lines of growth.

Upper latus (Fig. 4) a very acute-angled isosceles triangle. External surface almost smooth, and marked with irregular, indistinct, transverse ridges or periodic lines of growth, more strongly marked on the lateral margins. The lines of growth are continued on the inner surface, where they are very obliquely upturned, and meet on a raised, sharp-edged, median ridge, which extends to the apex. The portion marked with lines of growth indicates the extent to which the valve overlapped the scuta and terga, the raised ridge falling in between; and the small triangular smooth portion near the base indicates the extent to which the valve was covered by the corium or membrane lining the inside of the valves.

Valves of the Lower Whorls.—Although the specimen of *Brachylepas Naissanti*, figured by Dr. H. Woodward as *B. cretacea* (Geol. Mag., 1901, Pl. VIII, Fig. 4*a*), shows at the base of the capitulum from three to four whorls of imbricating valves in position, little knowledge can be gained of their inner structure. The specimen shows admirably the external arrangement of these valves, as well as their variation in shape and size, and enables one to gain some idea as to the number of valves constituting the several whorls. On the more complete side of the specimen figured there are fifty-four valves preserved, and if we reckon the same number for the other side the total would be 108. In all probability the number was greater, since some of the valves near the carina have a median notch in their basal margin, presumably for the external fixation of another valve.

From the specimens from Lüneburg we learn that the lower whorls of imbricating valves were probably four in number, with a few additional valves below the upper latera. The valves decrease in size outwardly, their bases stand almost on the same plane, and the median ridge of the outer valve closely corresponds to that of the valve immediately in front of it. When the valves were in position their external walls must have inclined at a greater angle than the walls of the carina and rostrum. All the valves have a strong median ridge with laterally divaricating growth-bands, which give to the lateral borders a serrated appearance, a feature strongly marked in certain valves. The median ridge sometimes stands out at the apex as a short spine.

Leaving out of consideration the additional valves below the upper latera, the innermost whorl is composed of valves that have a median semicircular notch in their basal margin (Figs. 7–9); some of these valves (Figs. 8, 9) have their inner surface thickened to form a sharp median ridge extending from the apex generally to about two-thirds the length of the valve, at which point a further ridge extends to each basi-lateral angle; others have their inner surface almost flat (Fig. 7). Surrounding this is a whorl of valves possessing an inwardly projecting angular ledge (Fig. 10), which is fixed into the median notch of the valve immediately in front of it (Figs. 11–14). This is followed by, perhaps, two further whorls of valves with an inwardly projecting ledge, the extremity of each angular ledge being fixed into the median notch of the valve in front. In this manner the basal ledges join to form a flat shelf or platform extending round the base of the capitulum (Fig. 11*b*).

The valves with a basal ledge vary in shape from an equilateral triangle to one with an acute apical angle, their external basal margin being almost straight and having a median notch. The basal ledge is formed by successive increments in the growth of the valve, and the edges of the several laminæ stand out freely as sharp ridges at the base of the valve. These ledges vary in width, possibly according to the position occupied by the valve, for in some of the smaller valves (Fig. 10) the basal ledge is wider than in others and projects inwards to an extent almost equal to the length of the valve itself. The ledge is angular in shape, and, as can be seen in one (Fig. 10) or two of the more perfect valves, is enlarged and slightly upturned at the apex, and is specially adapted to fix into the median notch of the valve immediately in front of it.

Much light is thrown on the inner structure and arrangement of these valves by the four valves (Fig. 11) still attached to one another. The inner valve (Fig. 11′) without a basal ledge, but with a median notch, is one of the valves of the innermost whorl, and probably occupied a position below the upper latus. This is followed by two valves (Fig. 11″) of the second whorl, which have an inwardly projecting basal ledge; the valve on the right hand, as can be seen in the inner view (Fig. 11*b*), is fixed into the median notch of the valve of the inner whorl by the extremity of its projecting ledge. The third whorl is represented by a single smaller valve with an inwardly projecting basal ledge, which is fixed into the median notch of the valve of the second whorl. This outer valve has a median notch presumably for the external attachment of yet another valve, and the presence of this supports the assumption that there were four whorls of valves at the base of the capitulum of this species. It is probable that the valves without a median notch formed additional valves below the upper latera, and in view of their structure it is difficult to conceive what other position they could have occupied. One of these valves is represented in Fig. 6, and it is much like the valves in the same position in the specimen of '*B. cretacea*', figured by Dr. H. Woodward (1901, Fig. 4*a*). The four attached valves from Lüneburg (Fig. 11) show also quite clearly how the valves with a basal ledge interlocked to form the shelf or platform round the base of the capitulum, and that the bases of these valves stood almost on the same plane. The other valves still attached to each other (Figs. 12, 13) probably occupied a position a little to the right or left of the region below the upper latera, and formed part of the first and second whorls, the valves (Figs. 9, 14) being disposed near the carina, and (Fig. 8) below the rostrum, since in the specimen figured by Dr. H. Woodward the lower latera are longest and narrowest under the carina.

It should be borne in mind that the valves here described and figured not only belong to different individuals, but to individuals in different stages of growth.

(*To be concluded in our next Number.*)

REVIEWS.

I.—Earth Features and their Meaning. An Introduction to Geology for the Student and the General Reader. By William Herbert Hobbs, Professor of Geology in the University of Michigan. 8vo; pp. xxxix, 506, with 24 plates and 493 text-illustrations. New York: The Macmillan Co., 1912. Price 12*s*. 6*d*. net.

THIS volume may be regarded to a certain extent as a companion to that on the *Characteristics of Existing Glaciers* (noticed in the Geological Magazine for 1911, p. 569). After introductory remarks on the aims of geology and the subdivisions of the science, the author deals with the figure of the earth and the materials composing the lithosphere, including the formation of crystals. He then passes on to consider the method of formation of rocks, and the contortions, thrusts, and faults to which they have been subjected. Earthquakes, with many instructive illustrations, and seaquakes; the rise of molten rock to the earth's surface, and the formation of volcanic mountains by exudation of lava and by ejected materials forming cinder cones, are next considered, the various subjects discussed so far occupying 148 pages.

More attractive, especially to the general reader, will be the descriptions of earth sculpture, which, including glaciation, occupy most of the remaining parts of the volume. Interesting are the descriptions of rock-weathering, and the author remarks: "How important is the cover of vegetation in retaining the rock mantle and the upper soil layer in their respective positions, as required for agricultural purposes, may be best illustrated by the disastrous consequences of allowing it to be destroyed. Wherever, by the destruction of forests, by the excessive grazing of animals, or by other causes, the mat of turf has been destroyed, the surface is opened in gullies by the first hard rain, and the fertile layer of soil is carried from the slopes and distributed with the coarser mantle upon the bottom lands. Thus the face of the country is completely transformed from fertile hills into the most desolate of deserts where no spear of grass is to be seen and no animal food to be obtained. The soil once washed away is not again renewed, for the continuation of the gullying process now effectively prevents its accumulation." Illustrations are given of a once wooded region in China now reduced to desert through deforestation, and of the 'Bad Lands' of the Colorado Desert.

The life-histories of rivers and the travels of underground waters; the influence of jointed and fractured rocks on the flow of inland waters and on the features produced by marine action (chasms, stacks, etc.), receive attention; so also the action of sun and wind in arid regions. The rise and fall of land are illustrated by evidences of uplifted sea-caves and notched cliffs, raised stacks and beaches, and by drowned rivers and submerged channels.

A large part of the work (140 pages) is devoted to glacial phenomena, including particulars of the Niagara Falls, and thus we find a repetition of much of the information and a number of the illustrations that were given in the author's earlier volume before-mentioned. He has, however, prepared the present work with the view of its serving as a guide to scientific students and tourists in Northern America and Europe who would take the book with them (they would be unlikely to carry two geological volumes); the descriptions and illustrations being selected as far as possible from localities likely to be visited. Prominence is thus given to glaciation because "the larger number of colleges and universities in both America and Europe are surrounded by the heavy accumulations that have resulted from former glaciations".

The concluding chapters deal with lake basins, and very briefly with the origin and form of mountains.

There are appendices containing notes on the quick determination of common minerals, descriptions of common rocks, notes on topographical and geological maps, and suggestions for itineraries.

The illustrations are profuse, well-executed, and effective. References to literature are given at the ends of chapters, and there is a good index.

II.—South African Geology.

Geological Survey of the Cape of Good Hope.—The fifteenth Annual Report of the Geological Commissioners of this Province, under the direction of Dr. A. W. Rogers, contains records of the work accomplished during 1910 (Cape Town, 1911). Dr. Rogers describes portions of the divisions of Beaufort West, Fraserburg, Victoria West, Sutherland, and Laingsburg. In dealing with the physical features he describes the 'pans' or bare, mud-covered surfaces on which water stands to the depth of an inch or so after rain; a few are well-defined, but most are ill-defined, measuring from 500 yards or less to over two miles in width. The clearly marked pans in the district are entirely surrounded by dolerite, the ill-defined and shallow pans occur on mudstone and sandstone. The depressions in the dolerite appear to be due primarily to rapid local disintegration of the rock, and to the wind having probably removed the loose material. Dr. Rogers gives some account of the Beaufort Series, and also of its many vertebrate remains from data supplied by Dr. R. Broom; he also describes the Nieuweveld coal, which occurs in fissures of a sandy mudstone, and near the southern end of great intrusions of dolerite. Professor Schwarz has suggested that the coal was carried to its present position by heated water. Analyses show that the coal, compared with other South African coals, contains low amounts of ash, but usually large amounts of moisture and also of volatile hydro-carbons. Particulars are given of the dolerites and also of granophyres, of the screes resulting from the weathering of the dolerite crags, and of other superficial accumulations.

Mr. A. L. Du Toit contributes an account of Maclear and portions of Engcobo, Mount Fletcher, Qumbu, and Mount Frere, a district formed of the Beaufort and Stormberg Series, with numerous sheets and dykes of dolerite. The higher part of the Stormberg Series consists of the Drakensberg volcanic beds, basaltic lavas with occasional thin beds of sandstone and volcanic ash, 3,000 feet and more in thickness. The great escarpment of the Drakensberg rises from 4,000 to more than 8,000 feet above sea-level. The Molteno Beds, which form the base of the Stormberg Series, beneath the Cave Sandstone, contains seams of coal, many plant-remains (*Thinnfeldia*, etc.), and blocks of silicified wood.

There is also a report by Mr. Du Toit on the copper-nickel deposits of the Insizwa, Mount Ayliff, East Griqualand. In this region the Beaufort Series, consisting of shales, flagstones, and thin sandstones, is penetrated by sheets and dykes of the Karroo dolerites, including gabbro; and the copper-nickel ores are confined, more or less, to the contact of gabbro with the altered sediment, but mostly to the igneous rock. The surrounding Beaufort Beds have been metamorphosed into biotite and cordierite hornfels.

III.—Wisconsin Geological and Natural History Survey.—The results of a *Reconnoissance Soil Survey of part of North-Western Wisconsin*, by Mr. S. Weidman, assisted by Messrs. E. B. Hall and F. L. Musback, have been published (Bulletin No. xxiii, Economic Series, No. 14, 1911). The foundation rocks of the area consist of Pre-Cambrian granite, schists, and quartzite, with Keeweenawan trap; of Potsdam Sandstone with shale and Magnesian Limestone of Cambrian age; and of St. Peter Sandstone and Trenton Limestone of Ordovician age. Superficial formations consist of clays, sands, gravels, and boulder-beds of Glacial age; of loess mainly of wind-drifted character and of later Glacial age; and Alluvial sand and gravel. A clearly printed map shows by colour fourteen kinds of soils over an area of 6,700 square miles, on a scale of one inch to 3 miles.

The soils (a term used to include surface soil and subsoil) are mostly derived from the superficial deposits, glacial drifts, and loess, but partly from the older rocks which appear in ridges and on some of the uplands. The land, however, is mostly of low elevation, few hills rising more than 200 or 300 feet, and occasionally 400 to 500 feet above the valleys. It is remarked that the character of the surface formation (Drift, etc.) is often largely determined by the underlying rock, and hence the various older geological formations are important factors in determining the character of the overlying soils.

Of the fourteen soils, seven are derived from the weathering of glacial drift, one from the loess, and five from the alluvial accumulations, including the 'muck' of the marsh and swamp lands. Twelve of these surface soils, mostly 6 to 8 inches deep, are described as loams, sandy or silty, and the subsoils are mostly of similar character, here and there a little more clayey, or containing in the case of one or two of the variable soils a little more coarse sand or gravel. These loams have been separated mainly on account of the differences in their mode of occurrence and the physical features of the land. The map is thus practically a map of the soils and subsoils, and the mechanical analyses are given from both.

Although large areas are covered by dense growths of woodland, evidence has been obtained to show the uniformity of many of the soils and subsoils over extensive tracts. The object is to point out the general character of the soils, the physical features of the land, and the climatic and agricultural conditions throughout the area. A detailed study of the soils in the populated areas is promised.

IV.—Fossil Human Remains from Peru.—The discovery of prehistoric human bones in the Cuzco Basin in the Central Andes of Peru is announced by Mr. Hiram Bingham, Director of the Yale Peruvian Expedition (*Amer. Journ. Sci.*, xxxiii, p. 297, 1912). The geological relations of the remains are described by Mr. Isaiah Bowman. The floor of the basin is from 11,000 to 11,500 feet above sea-level, and into it flow numerous streams which have dissected the marginal belt of alluvium and also the alluvial floor, bearing down quantities of land-waste. In one of these ravines are exposed the gravel deposits in which the human remains were found. Evidence of the occupation of the higher grounds by man is found in the presence of ashes, charred corn, broken pottery, bones of many kinds, etc., but no special antiquity can be assigned to these relics. The human bones in question were found beneath from 75 to 150 feet of gravel, portions of which had been eroded. They however afford no proof of great antiquity. With them were bones of *Canis* and *Bos* or *Bison*, and these again afford no proof of antiquity. Moreover, as pointed out by Mr. Bowman, it is within the limits of possibility "that the bluff in which the bones were found may be faced by younger gravel and that the bones were found in a gravel veneer deposited during later periods of partial valley filling". The human remains, which are figured, include parietal bone, ribs, femurs, etc. These and the other bones are described by Dr. George F. Eaton.

V.—Kelvingrove Museum, Glasgow.—*An Introduction to the Study of Fossils and Guide to the Palæontological Collections* in this Museum has been prepared by Mr. Peter Macnair, F.G.S., the Curator. (Glasgow, William Hodge & Co., 1912, pp. 89, price 3*d.*) The first part of this Guide deals with the mode of preservation of organic remains, with the indications they afford of physical conditions and of periods of time, with evolution and classification. Brief descriptions are given of the principal groups of Invertebrata and a few notes are appended on Vertebrata. The collection of fossils is arranged stratigraphically, and the great bulk consists of local specimens, so that in the second part, which deals with Historical Palæontology from Cambrian to Recent times, much more is naturally said about the Palæozoic than the Secondary and Tertiary forms of life. Specimens from the interesting volcanic neck in Arran of Rhætic and Lower Lias fossils are not separated, and the name *Gryphæa incurva* is used on one page and *G. arcuata* on another. Fossil leaves from the Tertiary beds of Mull and Mollusca from the Clyde Beds rightly receive special notice and illustrations. Many figures, indeed, are given throughout the work, and there is a useful index. The Guide has evidently been prepared with care, and should prove very useful to students and other visitors to the Museum.

VI.—Turtle Mountain, Alberta.—In 1903 a great landslide occurred along portions of this mountain, whereby seventy lives of people belonging to the town of Frank were lost, and much damage was done. A report of a Commission appointed to investigate the mountain has been published by the Department of Mines, Canada (Memoir No. 27, 1912). The object of the Commission was to determine whether the continued workings of the coal-mines or independent natural causes are likely to bring about other destructive landslides. The conclusions are that it is not possible to mine within a certain prescribed area without incurring the danger of precipitating a great landslide; and that irrespective of mining operations, and because of existing conditions, there is danger of a similar catastrophe. It is recommended that the greater part of the site of Frank town be abandoned on account of the unstable condition, from natural causes, of the North and South peaks; and if any mining is carried on within the danger area, it should be only under certain conditions, of packing the excavated areas, of taking not more than 50 per cent of the coal, etc. Numerous diagrams and pictorial views are given.

VII.—Brief Notices.

1. Geological Survey of the Transvaal.—We have received a copy of the excellent colour-printed geological map of portions of Marico and Rustenburg districts in the Transvaal Province, Sheet 9, issued by the Union of South Africa, Mines Department. The map is accompanied by a short memoir by Dr. W. A. Humphrey, entitled *The Geology of the country lying northwards from Zeerust* (Pretoria, 1911, pp. 27). The oldest rocks, igneous and sedimentary, belong to the Ventersdorp System, but occupy only a small area; the Bushveld Plutonic Complex (diabase, norite, and pyroxenite) and rocks of the Transvaal System occupy the greater part of the area, together with a small tract of quartzites, sandstones, and conglomerate belonging to the Waterberg System.

2. National Museum, Melbourne.—No. 4 of the Memoirs of this Museum (1912) contains a description and figures of a new Pecten (*P. præcursor*) from the Tertiary (Barwonian) of Southern Australia, by Mr. F. Chapman; also "Notes on a Collection of Tertiary Limestones and their fossil contents, from King Island", by the same author. In this article remains of a parasitic boring organism, probably a fungus, are described under the name *Palæachlya tuberosa*; other species described, and most of them figured, belong to marine Algæ, Foraminifera, Alcyonaria, Echinodermata, Chætopoda, Polyzoa, Brachiopoda, and Mollusca. The evidence of the fossils leads Mr. Chapman to regard the limestones as belonging to the Janjukian division.

3. Glacial Man.—A well-written review of the evidence relating to this subject has been contributed by Mr. R. S. Lull, Professor of Vertebrate Palæontology at Yale University (*Yale Review*, April, 1912). He refers to the Heidelberg man, as the most ancient known in the Old World, and the remains having been found in association with *Elephas etruscus* might be regarded as Pre-Glacial or Pliocene. Professor Lull comments also on the finding in the same layer of eoliths, "implements of the crudest workmanship, if indeed their apparent fashioning is not merely the result of use." In the New World no human bones "of generally accepted geologic antiquity are known".

REPORTS AND PROCEEDINGS.

Geological Society of London.

May 15, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The specimens (boring cores) exhibited included Silurian from Ware and Cliffe; Silurian or older rock from Harwich and Culford;

Devonian from Tottenham Court Road, Turnford, and Brabourne; Old Red Sandstone from Willesden, Chiswick, Southall, Richmond, Streatham, Beckton, and Crossness; Coal-measures and Carboniferous Limestone from Ebbsfleet, near Ramsgate.

The President stated that, no papers having been ready for presentation at the meeting, he had obtained the consent of the Director of the Geological Survey to exhibit the specimens. He drew attention to many points of interest which came up for consideration. The red rocks reached by the Richmond, Streatham, and Crossness boreholes had been originally classed, with some doubt, as Poikilitic or New Red Sandstone. He had himself, however, always held to the opinion that they were of Old Red Sandstone age and had so entered them in the Table of Borings published in the Report of the Royal Commission on Coal-Supplies; the recent borings at Willesden, Chiswick, and Southall confirmed this view.

Another point of interest to which he specially directed attention was the existence of rocks of Old Red Sandstone aspect, in the same region as rocks with Devonian fossils and of Devonian appearance. It would be of the greatest interest to ascertain the relations of the two types one to the other.

The exhibits included three of particular interest, namely, the rock from the Harwich boring showing a structure which was mistaken for a '*Posidonia*', but which Professor Watts had shown to be an accidental fracture; the Upper Old Red Sandstone fishes which had been obtained by Mr. Procter from the Southall cores; and the Carboniferous Limestone from Ebbsfleet, the first recorded occurrence of that formation in the South-East of England.

June 5, 1912.—Professor W. W. Watts, Sc.D., LL.D., F.R.S., Vice-President, in the Chair.

The following communications were read:—

1. "The Further Evidence of Borings as to the Range of the South-Eastern Coalfield and of the Palæozoic Floor, and as to the Thickness of the Overlying Strata." By Hon. Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S., F.S.A., F.G.S.

In this paper the author gives an outline of the history of the experimental borings made in order to verify Godwin-Austen's theory concerning "the Axis of Artois", which led to the discovery of the South-Eastern Coal-field. The first of these was at Netherfield (1872–5) near Battle (Sussex). Here the borehole, ending in Oxford Clay at a depth of 1,905 feet below the surface, showed that the Palæozoic floor is buried under so great a thickness of rock that it was advisable to look farther north for a site for further experiments. The second boring (1886–92), under the Shakespeare Cliff, Dover, on the site of the Channel Tunnel works, resulted in the discovery of the Coal-measures belonging to the Pennant or Middle Series of the Bristol and South Wales Coal-fields, at a depth of 1,100 feet below O.D. This affords a practical basis for further exploration. The extension of the coal-field to a distance of 8 miles north of Dover was proved by the boring (1897–9) at Ropersole, where the same Pennant Series occurred at 1,180 feet below O.D., and its extension in the intervening area about 5 miles to the west of Dover by a boring under the direction of M. Breton at Ellinge (1901–2), where the coal-field was struck at 1,286 feet below O.D.

In these three borings the strata of the Coal-measures are practically horizontal, a fact which, in the opinion of the author, implies that they form the bottom of a syncline with its long axis passing from Dover in a north-westerly direction parallel to the scarp of the North Downs.

The boring at Brabourne (1897–8), under the direction of Mr. Brady and the late Mr. Etheridge, gave the next fixed point in the inquiry. It established the fact that, at the base of the North Downs, the Palæozoic floor consists of highly inclined strata (in the opinion of the author, of Devonian age) at 1,789 feet below O.D. These are covered by Dolomitic Conglomerate and Triassic marls, the section being identical with that of the Mendip Hills in Somerset. It therefore marks the position in Kent of the Pembroke–Mendip anticline, which forms the southern boundary of the coal-fields of Bristol and of South Wales. It follows that the south-western boundary of the South-Eastern Coal-field is to be looked for at a sufficient distance east of Brabourne to allow of the presence of the Carboniferous Limestone and Millstone Grit, as shown approximately on the map.

These results, laid by the author before the Royal Coal Commission in 1903, led to further experiments under his direction. The first of these, at Waldershare (1904–7), proved the existence of the Coal-measures at 1,069 feet below O.D., in two distinct groups, the upper belonging to the Pennant Series as before with an average dip of 10°, and the lower with an average dip of 20°, belonging to the lower group of Coal-measures of Somerset, Gloucester, and South Wales. The second, at Fredville (1905–7), three miles north-east of Waldershare, reached the Palæozoic floor at 1,109½ feet, and entered the same lower series of valuable coal-seams, dipping at an angle of 17° (Journ. Roy. Soc. Arts, vol. lv, pp. 456–7, 1907). Further experiments have been carried on north and east of Dover, but their results are not yet available for scientific purposes. Thus a valuable coal-field has been proved over a large area, with its eastern and western boundaries as yet undetermined, as shown on the map.

Two further experimental borings to the north and west, carried out under the author's direction in 1910–11, led to most unexpected results. Hitherto the Coal-measures were either horizontal, or dipping in the normal fashion without signs of faulting, and there was every reason to believe that the Coal-measure trough would be struck, on the first site, at Chilham, about three miles south-west of Canterbury. Instead, however, of Coal-measures, Upper Silurian shales with *Monograptus priodon* formed the Palæozoic floor at 1,072 feet below O.D. In the second, at Bobbing, near Sittingbourne, hard Silurian grits and shales occurred at 1,070 feet below O.D. In both borings the Silurian rocks are nearly vertical, and bear marks of crushing. The northern boundary of the South-Eastern Coal-field is therefore to be sought in the district between Fredville and Chilham, and probably nearer to the former locality than to the latter.

The Silurian portion of the buried Palæozoic floor is then traced westwards through Cliffe, on the Thames below Gravesend, to Ware in Hertfordshire, and northwards through Essex to Harwich, Sutton, and Culford (Bury St. Edmunds). To the south of this the Devonian rocks occupy the area of London, and extend as far as the district of Croydon.

The varying thickness of the overlying rocks is also dealt with, and details are given of three sections, at Ropersole, Chilham, and Bobbing, in the hope that they may be useful to other explorers.

2. "Shelly Clay dredged from the Dogger Bank." By John Walker Stather, F.G.S.

The Dogger Bank fishermen frequently get in their nets a tough peaty material, which they call 'moorlog'. In a paper published in the *Essex Naturalist*, April and July, 1909, this 'moorlog' was described by Mr. H. Whitehead and Mr. H. H. Goodchild, with a report on the plant-remains by Mr. Clement Reid, F.R.S., and Mrs. Eleanor Reid.

In looking over some recently dredged 'moorlog' brought in by a Hull trawler, the author noticed that, adhering to the specimens of 'moorlog', was a dark silty clay, full of marine shells. These specimens of 'moorlog', with the associated shelly clay, were dredged in lat. 55° 24′ N. and long. 3° 10′ E., at a depth of 20 fathoms.

A collection of these shells was submitted to Mr. Clement Reid, who stated that they are all assignable to very shallow-water species, and probably flourished just beneath low-water level. This and other evidence seems to show that the 'moorlog' in this part of the North Sea rests upon a bed of shelly silt, and the shells in the silt together with the 'moorlog' point to great changes of level in the North Sea Basin.

CORRESPONDENCE.

THE CARVED CRAG '*PECTUNCULUS*' SHELL.

SIR,—I am very glad you have admitted to your pages an illustration of the interesting carved shell of *Glycimeris* [olim *Pectunculus*] found in the Red Crag at Walton-on-the-Naze.

Through the kindness of Dr. Marie Stopes I have been permitted to examine the specimen. In common with some others who have examined the shell, I feel sure that it is not a modern forgery, but an ancient work of art; the present fragile condition of the shell and the staining are proofs of that. The sculpturing is not that of a prentice hand, nor, as the marks show, done with a modern or metal instrument.

That it is not of Pliocene age I am also convinced, and would hazard the following explanation of its history.

The surface deposits of the district in which it was found contain palæolithic implements, proving the occupation of the area by primitive man on its elevation above the sea-level.

The Crag in those days would not be in the condition in which we now know it. It had not then been soaked to so great an extent with the iron-charged drainage waters that have percolated it from palæolithic times to the present day, reducing its shelly contents to their present condition, and anything buried in it then would be similarly changed with the other contents.

A palæolithic man graved the shell (note the breadth of the nose in connection with Professor Sollas' suggestion as to the affinities of cave man—a later man would not have made it so broad); it was buried with the owner in a grave dug down into the Crag, all traces of which interment with the perishable human remains would become obliterated in the subsequent ages, or if any were left would be overlooked by the finder, who was not, I believe, a skilled geologist, and who certainly was not expecting the prize that came in his way.

B. B. Woodward.

PS. Since writing the above I have re-examined the shell with Mr. A. S. Kennard and others. Mr. Kennard pointed out that the hinge-teeth in one place held a small fragment of matrix unlike that of the Red Crag adhering to other parts of the shell, and strongly resembling humus. This little piece of evidence, if correct, will further support the interment theory. Mr. Kennard further considers that the staining in the cuts, especially the mouth, are unlike Red Crag staining, though not modern. It had previously occurred to me that it looked as if red ochre, as known to the ancient hunters, had been rubbed into the cut.

Another friend has favoured me with an attempt to reproduce the carving from memory on a *Glycimeris* shell from the Red Crag of the locality, but his efforts have only served to emphasize the impossibility of reproducing with modern tools and modern conception of the human face, even in caricature, the quaint but characteristic sculpture on the shell in question.

ON A DISCOVERY OF FOSSILS IN THE WEKA PASS STONE, NEW ZEALAND.[1]

Sir,—While not wishing to defend *in toto* the position taken up by Professor Marshall and Messrs. Speight and Cotton on the Younger Rock Series of New Zealand, which has recently been assailed by Professor Park in this Magazine (December, 1911), I should like to announce a discovery of fossils in the Weka Pass Stone which has considerable historical interest. Professor Park in 1905 (Trans. N.Z. Inst., xxxvii, pp. 545–6) and in the paper mentioned stated that he was unable to find recognizable fossils in this rock, and came to the conclusion that the fossils previously reported by Haast and Hutton were probably derived from fallen blocks of the overlying Mount Brown Beds. Professor Park had not had access to the Geological Survey collections, in which there are undoubtedly Tertiary fossils from this rock, and may be pardoned for not recognizing as from the Weka Pass Stone certain fossils in the Canterbury Museum which are labelled simply 'Weka Pass' or 'Waipara'. He is certainly right in maintaining that fossils are not abundant in the Weka Pass Stone, as stated by Haast, for it is possible to search for hours without success. In a recent visit to the Waipara district, however, Mr. Cotton and myself had the good fortune to stumble across several specimens of *Pecten* (*Camptonectes*) *huttoni* (Park), and a single specimen of a *Cirsotrema* allied to *C. lyrata* (Zittel), two of the most characteristic fossils of the Oamaru Series (Lower Tertiary). This discovery proves that Hector, Hutton, and Haast were right in ascribing a Tertiary age to the Weka Pass Stone, and throws back the position to where it was on Hutton's death, viz. that if the Weka

[1] By permission of the Director of the Geological Survey of New Zealand.

Pass Stone is conformable to the Amuri Limestone, there is a Cretaceo-Tertiary formation in New Zealand, while if it is unconformable, there are distinct Cretaceous and Tertiary formations.

J. ALLAN THOMSON.

MINES DEPARTMENT,
GEOLOGICAL SURVEY BRANCH,
WELLINGTON, N.Z.
April 26, 1912.

TERTIARY FOSSILS IN THE WEKA PASS STONE, NEW ZEALAND.

SIR,—The discovery of Tertiary fossils in the Weka Pass Stone in the Lower Waipara district, as reported in this issue by Dr. J. Allan Thomson, is of special interest in connexion with the Cretaceo-Tertiary controversy now taking place in New Zealand. On four different occasions I had carefully searched for recognizable fossils in this rock in the typical Weka Pass District without result, and in consequence referred the Weka Pass Stone to the Cretaceous Waipara succession. This discovery, it should be noted, does not in any way affect the argument for or against a Cretaceo-Tertiary succession to New Zealand. What it does is to show that the unconformity between the Lower Tertiary and the Cretaceous must be placed, not above the Weka Pass Stone as done by me, but below it as contended by Hutton. By the aid of a sketch-map kindly made for me by Dr. Thomson I had no difficulty in finding the new fossiliferous locality in the Lower Waipara. Although fossils are scarce I succeeded in finding two fine examples of *Pseudamusium huttoni* (Park) and two of *Cirsotrema lyrata* (Zittel), both typical of the Tertiary Oamaru Series. The fossils occur in the lower third of the Weka Pass Stone, and are usually not many feet above the junction of the Amuri Limestone.

Hutton always contended for an unconformity between the Weka Pass Stone and Amuri Limestone. The latter is a hard grey chalky rock without bedding planes. Its upper surface on which the Weka Pass Stone rests, as seen along the escarpment facing Doctor's Creek in the Lower Waipara where the Tertiary fossils were recently found, is undulating and gently corrugated, and in places broken into angular fragments that have been recemented so as to present a rudely brecciated appearance. But the physical break is nowhere great, and since both the Weka Pass Stone and Amuri Limestone are tilted at the same angle and exposed in the same scarps it is frequently difficult to distinguish any trace of stratigraphical discordance. Nevertheless, the discovery of Tertiary fossils in the Weka Pass Stone is a splendid justification of Hutton's contention. Above Hutton's unconformity the fossils are typically Tertiary and below typically Cretaceous.

In North Canterbury the Lower Tertiary (Oamaru) Series rests on the Cretaceous (Waipara) Series, but in South Canterbury and North Otago it rests only on older Mesozoic or Palæozoic rocks. Where the Oamaru Series rests on these older rocks in the south it always begins with a series of terrestrial beds containing seams of brown coal, but where it rests on the Cretaceous rocks in the Waipara district the terrestrial beds are absent. It would thus appear that marine deposition began first in the north and gradually spread southward as the subsidence progressed. The marine Weka Pass Stone in the north is apparently contemporaneous with the terrestrial brown Coal-measures in the south. When subsidence began at the close of the Cretaceous the first areas to be invaded by the sea would naturally be the old Cretaceous basins, which would explain the early appearance in the north of *Pseudamusium huttoni* and *Cirsotrema lyrata*, both of which it should be noted pervade all the marine beds of the Oamaruian in the south.

The correlation of the Weka Pass Stone and the Ototara (Waitaki) Stone in the south, as urged by McKay, is opposed to the palæontological evidence, for whereas the Pareora fauna underlies the Mt. Brown (Waihao, Waitaki, Duntroon, Ototara) and Kakanui calcareous horizons, it everywhere overlies the Weka Pass Stone.

JAMES PARK.

OTAGO UNIVERSITY, DUNEDIN.
April 30, 1912.

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From a photograph by E. A. Kime, taken in 1912 at Newport, Isle of Wight.

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ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Professor John Milne, D.Sc., F.R.S., F.G.S., Hon. Fellow of King's College, London.

(WITH A PORTRAIT, PLATE XVII.)

IT falls to the lot of only a very few able men to take up some neglected branch of science, and by their genius, their energetic work, the discoveries they make, assisted by their personal charm and bonhomie, to be able to attract general attention to their researches, and so attain a great public success, filling with interest and enthusiasm the intelligent, and attracting even the veriest tyro within the circle of their investigation. Such has been the outcome of the life-work of our friend and associate of many years, Professor John Milne, whose untiring energy in the study of Seismology has obtained for it now a foremost place in the physical sciences as having most important bearings on the economy of the globe and the very existence of our race.

A Doctor of Science of Oxford University, an Honorary Fellow of King's College, London, Professor of Mining and Geology in the Imperial College, Japan (1875–95), and of Seismology in the University of Tokyo; decorated with the Order of the Rising Sun in 1895 by the Emperor of Japan; elected an F.G.S. in 1873; a Fellow of the Royal Society (1887); awarded the Lyell Medal by the Geological Society in 1894, and a Royal Medal by the Royal Society in 1908—Professor John Milne needs no introduction to our readers in order to commend him to a place in this Magazine among "Eminent Living Geologists".

Born at Liverpool, December 30, 1850, he was the only son of his father, John Milne, of Milnrow, and his mother, Emma Twycross, daughter of James Twycross, of Wokingham. John Milne (the son) was educated at a school in Rochdale, and at the Collegiate College, Liverpool; thence he was entered at King's College, London, and afterwards at the Royal School of Mines, Jermyn Street. After studying practical mining engineering in Cornwall and Lancashire, he spent a short time at the Bergakademie Freiberg, and thence visited the principal mining districts in Central Europe. On his return to England he was selected by Mr. Cyrus Field, Sir James Anderson, and others to report on the mineral resources of Newfoundland and Labrador, where he spent two years (Geol. Mag., 1874, pp. 76–7). Thence he visited Funk Island, a small barren rock now swept by the high tides of the Atlantic, but once the home of the Great Auk, and obtained a large collection of skeletons of this now extinct flightless bird, formerly so abundant around the coasts of all the northern lands, including our own Islands.

When only a schoolboy Milne paid a visit, without parental leave, in his holidays to Iceland, about the volcanic geology of which he early became interested by a school prize he had received.

In 1874 John Milne joined the expedition of Dr. Beke, which, under the auspices of the Royal Geographical Society and the Rothschilds, was sent out to fix the exact site of Mount Sinai. During this exploration he visited Cairo and made some interesting geological notes on its environs (printed in this Magazine for 1874, p. 353).

In 1875 Mr. Milne was appointed consulting engineer to the newly-formed Public Works Department of the Japanese Government, and it is characteristic of the man that, instead of going comfortably to his post by the P. and O. mail packet, he started from Hull on August 3, 1875, and made his way alone across Europe and Asia, following to some extent the line of the present Siberian Railway, then unheard of, and did not emerge at Shanghai until nearly a twelvemonth later. He landed at Göttenborg, crossed Norway, Sweden, and part of Finland, and so to St. Petersburg. It took Milne eleven months, following the old trade routes, and but few would care to endure the dangers and discomforts of travelling thus through Siberia, Central Asia, and China. His way led him across Russia and the Urals into Siberia, thence by camel through Mongolia until he reached "the Great Wall of China" on January 11, 1876. On one section of the route, for thirty-one days there were no roads, no houses, no bread, no vegetables, no washing, no change of dress day or night, plenty of snow, and from 40 to 50 degrees of frost.

For many days in the heart of China (where he was styled a "foreign devil" by the natives) he was carried in a palankeen attached to a couple of mules. It was not until February 24 that he reached Shanghai.

Professor Milne's experience of earthquakes began the first night he spent in Tokyo, where he was attached to the Department of Mines and Public Works. His residence provided for him by the Government was named 'Yama Gouchi', or the Mouth of the Mountain. It proved a fitting introduction to the country. During the night for a few minutes the dwelling creaked and groaned and rolled from side to side, pictures see-sawed on the walls, while the rings attached to the mosquito-curtains jingled in a high treble. His career as a seismologist may be said to have dated from that moment, and he has grappled with the intricacies of the subject ever since. How could one fail to become interested in earthquakes, where, as Professor Milne says, "one had earthquakes for breakfast, for dinner, and for supper, and to sleep on." He soon began to make progress in his study of the new science, and also to perceive the imperative need for widespread co-operation.

With the fresh enthusiasm engendered by the disastrous earthquake of February 22, 1880, when Yokohama bore the appearance of a town that had been bombarded, he issued a call for a public meeting, which met with a hearty response. General van Buren presided, and the large hall was crowded with several hundred Japanese and foreigners. The world's first seismological society was formed that evening—the Seismological Society of Japan—and it has done the pioneer work, as well as having been the most active and useful. It at once enrolled about 300 members, with Mr. J. Hattori as president and Professor Milne as honorary secretary. For fifteen years Milne held that office, and directed the Society's work; the results are shown in its twenty volumes of reports, now known to seismologists all the world over, containing as they do the groundwork of the subject.

The Japanese Government soon saw the wisdom of encouraging the new science, and it established an Earthquake Committee, which it still supports with an annual subsidy on an average of $10,000 per annum, reaching in some years as high as $25,000. Wherever there is a considerable earthquake, there by the first boat goes a seismologist, an engineer, and an architect, and every phase of the disturbance and its after-effect is carefully studied and a report prepared. At the present day there are 968 stations scattered all over the Japanese Empire where these movements are recorded, a special bureau to which the reports are sent and analysed, and a chair of Seismology established at the Imperial University. The first to be appointed was Professor Milne, who occupied the chair of Seismology until he left for England in 1895.

The greatest earthquake which occurred during Professor Milne's residence in Japan (1876–95) was that of 1891. "It occurred," says Milne, "at six in the morning. I got into the open in time to see the next house tumbling to pieces. This was in the capital, where the Imperial Hotel was ruined, and the University buildings considerably damaged; but the worst effects were further south. Nine thousand nine hundred and sixty-eight persons lost their lives, and the number injured exceeded a hundred thousand. Railways and bridges were destroyed, 400 miles of river and canal embankments smashed, and the sides of mountains fell out and formed lakes by damming up the rivers. The Government spent thirty millions of dollars in relief works and repairing damages; and as the earthquake just lasted 30 seconds, it may be said to have cost the Government alone a million a second."

Fewer large earthquakes have occurred since 1891—one at Tokyo (1894) cost twenty-six lives, and another in the northern provinces killed about three hundred people. That at Kamaishi in 1896, which caused a loss of thirty thousand lives, is said to have been due to enormous tidal waves which swept the coast. These waves are not uncommon off Japan. In 1855 one partially destroyed the town of Shimoda, where Perry landed and got his treaty; and in 1868 and again in 1877 such seaquake waves were felt along the coast of Japan from north to south, rising and falling at short intervals like an ordinary tide, only vastly bigger; they were due to earthquakes in South America. Disasters like that at Kamaishi probably owe their origin to disturbances close to the coast, and therefore the waves rushed in with greater violence. They may have been caused either by a submarine eruption or a gigantic landslip at the bottom of the ocean. The origin of the large earthquakes for many years past, felt along the eastern coast of Japan, has been traced to a point perhaps a hundred miles out to sea, and such a line lies on the synclinal folding which forms the sub-Pacific trough of the northern island. It is quite probable that this 'folding' is still in progress, and from time to time the crumpling crust reaches the limits of elasticity and suddenly breaks. This is probably the reason for 95 per cent of these disturbances. For the remainder volcanic explosions may account. And when it is considered that there are about a hundred volcanoes in Japan that have been active during the historic period, that is not a large proportion of terrestrial disturbances to lay to their charge.

In addition to the accumulated scientific knowledge which has resulted from these researches, the Government of Japan has derived no small economic advantage from Professor Milne's careful studies in seismology. The method of building bridges and houses has been entirely revolutionized. For example, the piers of bridges are now made thicker at their bases and taper upwards, instead of being built with straight sides as in Europe, and brick factory-chimneys have been replaced by structures of sheet-iron. A severe earthquake now would not cause one-fourth of the damage which would have been inevitable a few years ago.

Holidays that came at long intervals in Professor Milne's strenuous work at Tokyo were spent in the exploration of earthquake areas on the Pacific seaboard, from the Kuriles and Corea to Manila, Borneo, the Australian Colonies, and many volcanic islands. He also visited the United States. Professor Milne spent two decades in Japan, and on returning to England in 1895 he left behind him a well-trained staff in the Department of Seismology, and many well-equipped and actively-working observation-stations throughout the country.

His attachment to Japan was sealed by his marriage to Miss Tone Noritsune, and before he left for home the Mikado conferred upon him the Japanese Order of the Rising Sun and a pension as a token of His Majesty's appreciation of the value of Professor Milne's services in the cause of science during his long residence in Japan.

He soon settled at Shide, near Newport, not far from the centre of the Isle of Wight. Here he has been indefatigable; experimenting, comparing, writing. Most of the writing, like that done during his years in Japan, has gone into the transactions and reports of learned societies. *Earthquakes* (1883) and *Seismology* (1898) are his only works in book-form, although he has also published a *Miner's Handbook* and a book on Crystallography. This year he published a *Catalogue of Destructive Earthquakes, A.D. 7 to A.D. 1899*, contributed to the British Association Portsmouth Meeting, 1911 (issued as an octavo pamphlet, pp. 92); a most arduous and valuable piece of bibliographical research in Seismology.

"It would be extremely interesting to see all Milne's contributions brought together and methodically arranged. Only then could we fully grasp how great is the debt of the world to him.

"Early in his researches Professor Milne conceived the idea of his first seismograph for measuring the amplitude and period of earth vibrations. From noticing the long distances to which the movements of a violent shock reached, his attention was drawn to the fact that, simultaneously with a great shock, in far parts of the world where this could not be felt, other phenomena were noticed, such as the movement of water, the deflection of scientific instruments, etc. This led him to write in 1883, in his book on *Earthquakes*, 'it is not unlikely that every large earthquake might, with proper instrumental appliances, be recorded at any point on the land-surface of our globe.' He now knows this to be a fact, and from the proof of this surmise dates the progress of the new seismology."[1]

"After finding that the instrument recorded an earthquake somewhere, came the discovery that every earthquake gave rise to different types of waves which travelled on different paths. There are waves which proceed straight through the earth, and waves coming round its surface. From this observation Professor Milne showed that we can easily determine the distance of the seat of the disturbance from the recording instrument. By this means the correlation of two or three records from stations separated at sufficient distance gives the spot from which the disturbance radiated. But to-day that spot can be determined by one instrument alone. This discovery, as Professor Milne enthusiastically explains, was made by Prince Galitzin, a Russian seismologist, who points out that the first movement of the indicator is in the direction of the origin."

Professor Milne has certainly selected a spot for his home as far as may be from these earthquake disturbances which have made him famous. "It is a quaint conceit" (writes Mrs. Lou Henry Hover[1]) "that to the utter quiet of this pretty, tree-encircled old house, with its grassy stone-stepped terraces, leading down towards the little valley, with the great peaceful downs rising at its back, should come the earthquakes of the world to be classified and studied. But come they do, and a vast amount of work they make for Professor Milne and his clever Japanese assistant, Mr. Hirota".

Dr. Milne has been instrumental in establishing sixty or more seismological stations throughout the world, whose reports come some of them monthly, some twice yearly, and some when a chance boat brings them. These stations include Calcutta, Madras, Bombay, Cape of Good Hope, Adelaide, Melbourne, Sydney, Perth, Victoria, Australia, Fiji, Ascension, St. Helena, Seychelles, Mauritius, and Cocos Islands; in America there are stations at Baltimore, Philadelphia, Mexico, and the Argentine. In Argentina there will shortly be five stations. There is a seismological station at Honolulu and another on Fanning Island in the middle of the Pacific. As a rule the stations on isolated islands are erected and maintained by the Cable Companies, who recognize the benefits to be derived from Professor Milne's earthquake studies. There are a vast number of stations in Japan, and the Japanese Government expend £5,000 annually on seismographical research, and Russia does the same. There are several important seismological stations in Russia, including Tashkend, Tiflis, and

[1] Bulletin Seismological Society of America, Stanford University, California, vol. ii, No. 1, p. 5, March, 1912.

Irkutsk. In Chili they also spend a considerable sum annually on the science. Every six months a circular containing all the recent registers is sent out to all the stations. This is practically a labour of love on Professor Milne's part, for he holds no official position. He has already sent out forty-five of these circulars, as well as many other reports for the British Association, of whose Seismological Committee he has been honorary secretary for thirty-one years.

The wonderful success attending Professor Milne's work is of course owing to the fact that he is the inventor and designer of nearly all the apparatus in use in his laboratory at Shide, and not only there but in well-nigh every quarter of the globe.

Professor John Milne, D.Sc., F.R.S.
From a photograph taken in 1896.

Numerous investigations outside earthquakes have been carried on by Dr. Milne. In conjunction with his friend Mr. Macdonald, of the Japanese Railway Department, he perfected an instrument on the same principle as the seismograph for recording the vibrations of trains. By this means any defect in the engine or the permanent way can be at once discovered. These instruments are universally in use on Japanese railways, and will probably be taken up by British lines presently.

Notwithstanding the remoteness of Shide House, and the desire and necessity for quietude in order to carry out practically the various problems which Dr. Milne's active and inventive brain may suggest, his visitors' book shows that he has only imperfectly accomplished his object. From all parts of England these pilgrim questioners have come, from Scotland and from Ireland. All the great Universities are represented— Edinburgh, Glasgow, Cambridge, Oxford, Sheffield

University, University College, London, Bristol University, Tokyo, Jamaica, California, Corfu, Bermuda, Milan, Paris, Pennsylvania, and Greenwich Observatory. His visitors include the Presidents of many learned societies and Princes of various countries. His Majesty King George, who was then Prince of Wales, accompanied by the late Duke of Clarence, visited Dr. Milne's Earthquake Establishment in Japan, and the present Prince of Wales, while a cadet at the Royal Naval College, Osborne, visited the station at Shide.

It seems a lifetime to recall, as I am able, the days when Professor John Milne was a student at the Royal School of Mines, a keen young geologist and mineralogist, and an enthusiastic follower of Professor Sir Warington Smyth, his instructor.

What is the secret of his attractiveness and his perennial youth? It is the cheerful light-heartedness of his disposition, which has never deserted him in all these years, but has sustained his spirit and given him the power to infect others with the same interest and enthusiasm in his work and carry them along with him.

The phenomena of earthquakes are at once his serious study and his delightful occupation. For him the earth is like an Æolian harp, it vibrates to the influence of every heavenly body, it is played upon by the sun's tropic rays, buffeted by the unruly ocean in its lap, resounds to the stress of the storm-winds, is shaken by earthquakes and volcanoes from pole to pole, yet repeats, by a tender throb to his seismometer at Shide, the faintest vibration even from a distance of twelve thousand miles away.

H. W.

LIST OF PUBLICATIONS BY PROFESSOR J. MILNE, D.SC., F.R.S., F.G.S.[1]

1874. "Notes on the Physical Features and Mineralogy of Newfoundland": Quart. Journ. Geol. Soc., vol. xxx, pp. 722–45.

"Geological Notes from the Neighbourhood of Cairo": GEOL. MAG., Vol. I (2), pp. 353–62.

1875. "Geological Notes on the Sinaitic Peninsula and North-Western Arabia": Quart. Journ. Geol. Soc., vol. xxxi, pp. 1–28.

1876. "Ice and Ice-work in Newfoundland": GEOL. MAG., Vol. III (2), pp. 303–8, 345–50, 403–10.

1877. "On the Action of Coast-ice on an Oscillating Area": Quart. Journ. Geol. Soc., vol. xxxiii, pp. 929–31. [Abridged.]

"Considerations on the Flotation of Ice-bergs": GEOL. MAG., Vol. IV (2), pp. 65–71.

(With ALEXANDER MURRAY) "On the Rocks of Newfoundland": ibid., pp. 251–62.

"A Visit to the Volcanoes of Oshima": ibid., pp. 193–9.

"Across Europe and Asia. Travelling Notes": ibid., pp. 289–97, 337–46, 389–406, 459–68, 511–18, 557–68; Vol. V (2), pp. 29–37, 62–73.

1878. "On the Form of Volcanoes": ibid., Vol. V (2), pp. 337–45.

1879. "Journey across Europe and Asia": Trans. Asiatic Soc. Japan, vol. vii, pp. 1–72.

"A Cruise among the Volcanoes of the Kurile Islands": GEOL. MAG., Vol. VI (2), pp. 337–48.

"Further Notes upon the Form of Volcanoes": ibid., pp. 506–14.

Notes on Crystallography and Crystallo-physics. London: Trübner and Co.

"On the Stone Age in Japan": Rep. Brit. Assoc. Adv. Sci., p. 401.

[1] Compiled by C. P. Chatwin, F.R.M.S.

1880. "Note on the Geographical Distribution of Volcanoes": GEOL. MAG., Vol. VII (2), pp. 166–70.

"Note on the Cooling of the Earth": ibid., pp. 99–102.

"Experiments on the Elasticity of Crystals": Min. Mag., vol. iii, pp. 178–85.

"List of Japanese Minerals, with notes on species which are believed to be new": ibid., pp. 96–100.

"A large Crater (Asosan, in Kiushiu, Japan)": *Popular Science Review*, vol. xix, pp. 336–45.

Catalogue of the Minerals, Rocks, Fossils, Shells, and Casts contained in the Geological Department of the Imperial College of Engineering (*Kobudai-gakko*). Tokyo.

"Notes on the Stone Implements from Otaru and Hakodate, with a few general remarks on the prehistoric remains of Japan": Trans. Asiatic Soc. Japan, vol. viii, pp. 61–91.

"Seismic Science in Japan": Trans. Seism. Soc. Japan, vol. i, pp. 3–37; and *Japan Gazette*, May 1, 1880.

"Notes on the Recent Earthquakes of Yedo Plain, and their effects on certain buildings": Trans. Seism. Soc. Japan, vol. ii, pp. 1–38.

"The Peruvian Earthquake of May 9th, 1877": ibid., pp. 50–96.

1880–1907. Numerous articles in *Nature*, the most important being on—

LOCAL SEISMOLOGY: Japan, vol. xxii (1880), p. 208; vol. xxv (1882), pp. 125–6; vol. xxvi (1882), pp. 627–31; vol. lxvi (1902), p. 202. West Indies, vol. lxvi (1902), pp. 56–8, 107–11, 151–3, 370–2; vol. lxvii (1903), pp. 91–2. Strasburg, vol. lxv (1902), p. 438. Austria, vol. lxv (1902), pp. 475–6. Galicia, vol. lxvii (1903), p. 235. Isle of Wight, vol. lxvii (1903), p. 348.

GENERAL SEISMOLOGY: vol. xxv (1882), p. 126; vol. xxviii (1883), pp. 367–70; vol. xxix (1884), pp. 456–7; vol. xxxii (1885), pp. 259–62; vol. xxxv (1886), pp. 152–3; vol. xlix (1894), pp. 301–2; vol. li (1895), p. 548; vol. lix (1899), pp. 368, 414–16, 487–9; vol. lxv (1902), pp. 202–3; vol. lxvii (1903), pp. 538–9; vol. lxviii (1903), pp. 69–70; vol. lxxiv (1905), pp. 42–4; vol. lxxv (1907), pp. 402–3.

BUILDINGS AND ENGINEERING: vol. xxix (1884), pp. 290–1; vol. xlv (1891), p. 126.

PENDULUM SEISMOMETERS: vol. xxxvii (1888), pp. 570–1; vol. liii (1895), pp. 180–2.

HISTORY OF INVESTIGATION IN JAPAN: vol. xxxv (1887), p. 559.

1881. "A portion of the Seismological Apparatus used in Japan." 4to. Tokyo.

"The Stone Age in Japan; with notes on recent geological changes which have taken place": Journ. Anthrop. Inst., vol. x, pp. 389–423.

"Experiments in Observational Seismology": Trans. Seism. Soc. Japan, vol. iii, pp. 12–64.

"Notes on the Great Earthquakes of Japan": ibid., pp. 65–102.

"Notes on the Horizontal and Vertical Motion of the Earthquakes of March 8, 1881": ibid., pp. 129–36.

"Evidences of the Glacial Period in Japan": Trans. Asiatic Soc. Japan, vol. ix, pp. 53–86.

(With THOMAS GRAY) "A contribution to Seismology (Earthquake Observations and Experiments in Japan)": Rep. Brit. Assoc. Adv. Sci. 1881, pp. 646–7; Phil. Mag., vol. xii, pp. 356–77.

"The Earthquake of December 23, 1880": *The Chrysanthemum* (Yokohama), 1881.

Papers on Japanese Earthquakes and Volcanoes: *Japan Gazette*, 1881 and 1882.

1881–95. Reports of the Committee for Investigation of the Volcanic and Earthquake Phenomena of Japan: Rep. Brit. Assoc. Adv. Sci. for the years 1881 to 1895 inclusive.

1882. "Earth Movements": GEOL. MAG., Vol. IX (2), pp. 482–5.

1882. (With THOMAS GRAY) "On Seismic Experiments": Proc. Roy. Soc., vol. xxxiii, pp. 139–40. [Abstract.]

"Notes on Koropok-guru or Pit-Dwellers of Yezo and the Kurile Islands": Trans. Asiatic Soc. Japan, vol. x, pp. 187–98.

"The Distribution of Seismic Activity in Japan": Trans. Seism. Soc. Japan, vol. iv, pp. 1–30.

"Utilization of the Earth's Internal Heat" (a discussion opened by J. Milne): ibid., pp. 61–72.

"Suggestions for the Systematic Observation of Earthquakes": ibid., pp. 85–117.

"Earthquake Motion": *The Chrysanthemum* (Yokohama), 1882.

1883. (With THOMAS GRAY) "On the Elasticity and Strength-constants of Japanese Rocks": Quart. Journ. Geol. Soc., vol. xxxix, pp. 139–40. [Abridged.]

(With THOMAS GRAY) "On Seismic Experiments": Phil. Trans., vol. clxxiii, pp. 863–83.

"Earth Tremors": Trans. Seism. Soc. Japan, vol. vii, pt. i, pp. 1–15.

"Earth Pulsations": ibid., vol. vi, pp. 1–12.

1884. "On 387 Earthquakes observed during two years in North Japan": ibid., vol. vii, pt. ii, pp. 1–87.

Recherches sur les tremblements de terre au Japon. Congrès Géologique de Berlin, Yokohama, 1884.

1885. "Seismic Experiments": Trans. Seism. Soc. Japan, vol. viii, pp. 1–82.

"Construction in Earthquake Countries": Proc. Inst. C. E., vol. lxxxiii.

1886. "The Volcanoes of Japan": Trans. Seism. Soc. Japan, vol. ix, pt. ii, pp. 184.

Earthquakes and other Earth-movements. 1st ed. London: International Science Series.

1887. "On a Seismic Survey made in Tokyo in 1884 and 1885": Trans. Seism. Soc. Japan, vol. x, pp. 1–36.

"Earth Tremors in Central Japan": ibid., vol, xi, pp. 1–78.

"Earthquake Effects, Emotional and Moral": ibid., pp. 91–114.

"On Construction in Earthquake Countries": ibid., pp. 115–74.

1888. Several papers in Trans. Seism. Soc. Japan, vol. xii: "Effects of Earthquakes on Lower Animals," pp. 1–4; "Modern Pendulum Seismometers," pp. 22–8; "The Gray–Milne Seismograph and other Instruments at Tokyo," pp. 33–48; "Sound Phenomena of Earthquakes," pp. 53–62; "Relative Motion," pp. 63–6; "Movements in Buildings," pp. 67–76; "Seismic Problems," pp. 107–14.

1889. Several papers in Trans. Seism. Soc. Japan, vol. xiii, pt. i: "Earth Tremors in Central Japan," pp. 7–20; "Distribution of Motion in a small Area," pp. 41–90; "Japanese Earthquakes in 1886," pp. 91–132. Vol. xiv: "Earthquake Motion," pp. 1–42; "Effects on Buildings," pp. 43–83; "Information for Builders," pp. 229–46.

"Seismic Work in Japan," and "On the Vibration of Railway Trains": Rep. Brit. Assoc. Adv. Sci., p. 492.

"Building in Earthquake Countries": Proc. Inst. C. E., vol. c.

1890. Papers in Trans. Seism. Soc. Japan, vol. xv: "Seismometry and Railway Trains," pp. 23–30; "Japanese Earthquakes," pp. 93–8; "Report of Observations for the year 1887," pp. 99–126; "Earthquakes in connexion with Electric and Magnetic Phenomena," pp. 135–62.

1891. "On Phenomena which might be observable if the hypothesis that Earthquakes are connected with Electrical Phenomena be entertained": Rep. Brit. Assoc. Adv. Sci., p. 583.

1892. (With W. K. BURTON) *The Great Earthquake in Japan, 1891.* Yokohama and London [Stanford].

(With W. K. BURTON) *The Volcanoes of Japan.* Pt. i: Fujisan. Yokohama, Shanghai, Hong-kong, and Singapore: Kelly & Walsh.

1893. *The Miner's Handbook.* London: Lockwood.
"On Earth Pulsations and Mine Gas": *Colliery Guardian*, vol. lxvi, p. 59; Trans. Fed. Inst. Mining Eng., vol. v, pp. 203–18.
"Notes on a Journey in North-East Yozo and across the Island": Supplementary Papers, R. Geogr. Soc., vol. iii, pt. iv, pp. 479–518.
1894. "Seismic, Magnetic, and Electric Phenomena"; "Mine Gas and Earth Pulsations"; "Horizontal Pendulums": Seism. Journ. Japan, vol. iii.
1895. "A Catalogue of 8,331 Earthquakes recorded in Japan between 1885 and 1892": ibid., vol. iv.
1896–1910. Thirty-three Reports of the Committee for Seismological Investigation (containing about 400 separate records). Rep. Brit. Assoc. Adv. Sci. for the years 1896–1910 inclusive.
1896. "Movements of the Earth's Crust": Geogr. Journ., vol. vii, p. 229.
1897. "Sub-oceanic Changes": ibid., vol. x, pp. 129–46, 259–89.
"On certain Submarine Geological Changes": Rep. Brit. Assoc. Adv. Sci. 1897, pp. 716–17.
1898. *Seismology.* London: International Science Series.
"Recent Advances in Seismology": Proc. R. Inst. Gt. Brit., vol. xv, pp. 326–36; Rev. Sci. Paris, ser. IV, vol. ix, pp. 357–64.
"Recent Seismology: I. Earth-movements which we feel. II. Unfelt Movements of the Earth's Crust": *Nature*, vol. lvii, pp. 246–9, 272–6.
1899. "Seismology in relation to the Interior of the Earth": Rep. Brit. Assoc. Adv. Sci. 1899, p. 802.
"Civil Time . . .": Geogr. Journ., vol. xiii, pp. 173–94.
1900. "Large Earthquakes recorded in 1899": Rep. Brit. Assoc. Adv. Sci. 1900, pp. 812–13.
1902. "World-shaking Earthquakes in relation to Volcanic Eruptions in the West Indies": ibid., 1902, pp. 682–3.
1903. "Seismological Observations and Earth-Physics": Geogr. Journ., vol. xxi, pp. 1–22.
1905. "Recent Advances in Seismology": Rep. Brit. Assoc. Adv. Sci. 1905, pp. 340–1.
"A New Island [in the Pacific]": Geogr. Journ., vol. xxv, pp. 531–3.
"Preliminary Notes on Observations made with a Horizontal Pendulum in the Antarctic Region": Proc. Roy. Soc., ser. A, vol. lxxvi, pp. 284–95.
1906. "Recent Advances in Seismology" [Bakerian Lecture]: ibid., vol. lxxvii, pp. 365–76.
"Certain Earthquake Relationships": Rep. Brit. Assoc. Adv. Sci. 1906, pp. 573–4.
1908. "The Duration and Direction of Large Earthquakes": ibid., 1908, p. 706.
1912. *A Catalogue of Destructive Earthquakes, A.D. 7 to A.D. 1899.* Brit. Assoc. Adv. Sci. Portsmouth, 1911, 8vo, pp. 92, 5*s*.

Sedgwick Museum Notes.

II.—Notes on the Genus *Trinucleus*.—Part I.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XVIII.)[1]

Introductory Remarks.

The large collection of specimens of the various species of *Trinucleus* from British Ordovician beds which is available for study in the Sedgwick Museum offers unsurpassed opportunities for determining the characters of the members of this interesting genus as represented in

[1] Plate XIX will accompany the second part of this paper in the September Number.

the British Isles. The following notes have been compiled from a comparative study of this material supplemented by specimens from the Jermyn Street Museum and elsewhere. The frequent addition of specimens to the collection at Cambridge since Salter and McCoy's time have allowed for a more comprehensive and complete survey to be made than was then possible, though several doubtful points still await better material before they can be cleared up.

My attention was first directed several years ago to the inadequate or imperfect descriptions of the fringe; and accordingly the study of the structure of this portion of the head-shield forms the first paper in the series which is intended subsequently to deal with the other characters of the members of this genus, with a view to a revision of the British species.

I. The Fringe.

The structure of the 'fringe' around the head-shield of *Trinucleus* has been studied by many palæontologists from time to time, but in the case of the British species of the genus the investigation of its characters has sometimes lacked precision owing to the poorness or scarcity of the material available. Our knowledge, moreover, has mainly been confined to the upper surface of the fringe, and the features of its lower surface have very rarely been described. It is remarkable that it has not been more noticed that the upper and lower surfaces frequently show a considerable difference in the arrangement or development of the pits, so that casts of the two surfaces are dissimilar and lead to confusion in describing the specific characters unless this fact is clearly recognized.

From the examination of a large series of specimens of the principal British species it has been found possible to supply to some extent this gap in our knowledge, though some points in the structure and relation of the various types remain obscure for the present.

1. *Double Nature of the Fringe.*

With regard to the nature of the fringe itself, the presence of a marginal suture in all the species seems to be now generally assumed,[1] though its existence has not been always demonstrated, and in most of the British species can rarely be directly observed. We should expect it to be most clearly noticeable in those forms in which the fringe obviously consists of two lamellæ separated by an intervening space, as in the species from the Bala Beds of the Onny River, usually now referred to *T. concentricus*, Eaton. The suture in these specimens from Shropshire in which the shell is preserved is seen just above the angular outer edge, as Oehlert[2] states is the case in *T. Bureaui*, Oehlert. But the hourglass-shaped hollow pillars representing the opposite and communicating pits on the upper and lower surfaces are continuous and show no transverse plane of fission, though they break at the waist when the fringe is horizontally split; the internal tubes are also uninterrupted (Pl. XVIII, Figs. 1*a*, 1*b*).

[1] Woods, article on *Trilobita* in Camb. Nat. Hist., vol. iv, ch. viii, p. 226, 1909.

[2] Oehlert, Bull. Soc. Géol. France, ser. III, t. xxiii, p. 317, text-figs. *k* and *l*.

In the British forms referred to *T. seticornis*, His., or *T. Bucklandi*, Barr., those specimens which have the shell of the fringe preserved fail also to show a horizontal plane of fission traversing the tubes which likewise form continuous hollow pillars connecting the upper and lower lamellæ separated by an intermediate space. The same feature is observable in *T. Nicholsoni*, Reed. Probably the perforation and union of the upper and lower pits into complete tubes are of a secondary nature, and we may thus account for the obliteration of the median horizontal interlamellar space. Oehlert (op. cit.) does not consider that the lamellæ forming the upper and lower plates of the fringe were really completely perforated, or that direct communication by continuous canals was ever established; for he holds that a chitinous layer and conjunctive tissue existed on the inner side of each lamella, preventing a free passage. But the unbroken continuity of the tubes formed by corresponding pits can be distinctly observed without a shadow of doubt in transverse sections of the fringe of several British species, e.g. *T. subradiatus*, Reed, and it is particularly clear near the outer margin in this species and in those cases in which the lamellæ are nearly or quite in contact.

The duplicate nature of the fringe was indirectly recognized by Salter [1] in the case of *T. Lloydi*, Murchison, for he states the fringe is hollow in this species; though he had previously [2] put forward the incongruous view that the fringe originated by the lateral fusion of radial spines round the front of the head-shield. The presence of an internal cavity in *T. Lloydi* may, therefore, have been conjectured by him as due to the secondary hollowing out of a solid plate. Rouault,[3] though suggesting that the interlamellar cavity in the biconvex fringe of *T. Pongerardi*, Rouault, may have acted as a float, did not express the view that it resulted from the internal excavation of a simple thick plate.

If the fringe can be regarded as of the nature of an expanded border (upper lamella) and doublure (lower lamella) in a head-shield with a marginal suture, we should expect to find the inner edge of the doublure, i.e. the lower lamella or plate, free; and such is seen to be the case in well-preserved specimens of *Trinucleus.*

Whether a fusion of the two lamellæ has taken place in those cases in which the fringe seems solid and simple (e.g. *T. subradiatus*) is difficult to decide, as the shell is mostly unknown, but it may be regarded as probable. In other cases the lamellæ may have been so closely pressed together as to practically form one plate without definite fusion.

Beecher's view that the lower plate of the fringe represents the conjoint free cheeks of more highly specialized Trilobites need not be here discussed. At any rate, extensive modification in their structure must have subsequently taken place, if this theory is correct, and it is advisable to postpone the consideration of the homology and origin of the fringe till we have completed our study of the genus.

[1] Salter, Dec. Geol. Surv., No. vii, pl. vii, fig. 3, 1853.

[2] Salter, Proc. Geol. Soc., vol. iii, p. 251, text-figs., 1847.

[3] Rouault, Bull. Soc. Géol. France, ser. II, vol. iv, p. 311, pl. iii, figs. 1, 1*a–c*, 1846.

2. *Character of the Pits.*

The nature and development of the pits which dot the upper and lower surfaces of the fringe vary somewhat. Generally they are merely conical pits of greater or less depth, the apices of opposite and corresponding ones frequently touching one another and sometimes communicating by a pore, thus forming hourglass-shaped structures in a cross-section of the fringe. The pores when occurring at the apex of each pit may connect by means of a special minute pit or short tube, or the apices may be directly in contact. Occasionally the floor of each pit is raised in the centre into a low rounded boss or mamelon, the centre of which is depressed and perforated, and it is connected with the corresponding pit on the opposite surface by a short fine tube, as is beautifully shown in some casts of the so-called *T. concentricus* from the Onny River (Pl. XVIII, Fig. 1). The same structure is observable in the larger pits at the genal expansions in most British specimens of *T. seticornis*, and in *T. Bucklandi* from Girvan. Barrande [1] did not show this plainly in his figures of *T. Bucklandi* from Bohemia. In his figures of *T. ornatus* (op. cit., pl. xxix, figs. 7, 8), he illustrated the common type of pit in the genus, consisting of a subconical circular depression with a small pore in the centre of the floor.

3. *Arrangement of the Pits.*

The pits of successive concentric rows are in some cases sunk in radial grooves or may be fused more or less completely so as to form radial sulci. In the most extreme cases (e.g. *T. hibernicus*, Reed [2]) the pits completely lose their identity and the perforations then alone indicate the number of pits which have amalgamated (Pl. XVIII, Fig. 2). All stages between the simple linear arrangement of pits in radial lines and their depression into grooves and fusion can be traced; and the definiteness, straightness, and elevation of the dividing radial ridges likewise vary from the extreme development of *T. fimbriatus*, Murchison,[3] to the scarcely differentiated structures in *T. Nicholsoni*.[4] Frequently different stages occur in the same species or in different parts of the fringe of the same individual (e.g. *T. Murchisoni*, Salter [5]).

The increase in the number of pits in the same concentric row is brought about by intercalation, and this intercalation does not seem to take place at any definite point in the row, judging from those cases (e.g. *T. concentricus* from the Onny River) in which it has been most clearly observed in the marginal (i.e. outermost) row (Pl. XVIII, Figs. 4, 7, 12).

On the other hand, the addition to the number of concentric rows

[1] Barrande, Syst. Silur. Bohême, vol. i, pl. xxix, figs. 10–17; pl. xxx, figs. 14–16.

[2] Reed, Geol. Mag., Dec. IV, Vol. II, p. 52, Pl. III, Figs. 2–7, 1895.

[3] Murchison, Silur. Syst., t. xxiii, fig. 2 (head only); McCoy, Syn. Brit. Pal. Foss. Woodw. Mus., p. 146, pl. iE, fig. 16.

[4] Reed, Geol. Mag., Dec. V, Vol. VII, p. 212, Pl. XVI, 1910.

[5] Salter, Siluria, 2nd ed., p. 50, fig. 7; id., Mem. Geol. Surv., vol. iii, p. 515, pl. xiB, fig. 4.

as distinct from the addition to the number of pits in the same row has so far been always traced to the division of one of the pits, and the new row starts off from the inner half of such a transversely bisected pit (Pl. XVIII, Figs. 5, 11). Such is the origin of the second row in the case of *T. Bucklandi* and of the extra rows of small pits on the 'roll' of the fringe of *T. seticornis.* Pits arising in this way by fission lie in the same radial lines as those of the originating row, but those developed by intercalation in the same row disturb the regular radial arrangement and lead to alternation in the pits of successive rows or to irregularity in their arrangement.

The base of the glabella is not always the centre of the circle to which the radial lines of pits in the fringe converge. The point of convergence may be situated further forward, and towards the genal angles the lines may therefore slope back, giving a fan-like arrangement. If the pits are not in sunken grooves this shifting forward of the centre leads to the appearance of alternation of pits in successive rows as the genal angles are approached (e.g. *T. Lloydi*).

With regard to the pits on the expansions of the fringe at the genal angles or posterior outer angles of the cheeks, there seems to be no definite rule; in all the species they are added and interpolated irregularly, and even in the same species there is considerable variation in their number and position which is not entirely due to differences of age.

4. *Differences in the Upper and Lower Surfaces of the Fringe.*

The upper and lower surfaces of the fringe in many species of *Trinucleus* show a considerable difference in the development and arrangement of the pits, as Salter long ago noticed. The concentric rows on the two surfaces may or may not correspond even in number, and radial grooves may only be developed on one surface and not on the other or in different parts of the two surfaces. The aspect of the two surfaces is therefore frequently different, and this is especially noticeable in the case of impressions of the surface. In most specific descriptions, however, only the characters of the upper surface are recorded, and unfortunately this is occasionally unavoidable owing to our imperfect knowledge of the lower surface.

4*a*. *Lower Surface of Fringe.*

With regard to the lower surface of the inferior lamella or plate of the fringe, we may first note that it is rarely either uniformly flat or gently convex or weakly concave as is the upper lamella. In nearly every case it is more or less angulated at one of the concentric ridges some distance inwards from the outer edge. This angulation may be feebly marked, particularly near the genal angles (e.g. *T. Goldfussi*, Barrande), or it may be quite absent (*T. Pongerardi*), but usually traces of it are discernible. Where it is strongly developed the division of the lower surface into an outer more or less horizontal flat band and into an inner inclined flat or more generally concave band is at once noticeable. Usually these bands are of unequal width, the outer one being generally of regular and smaller width and the inner one variable but widening considerably towards the genal angles and there corresponding to the genal expansions at the inner edge of the upper lamella. The distribution and character of the pits on the two bands have generally marked peculiarities, as will be mentioned in the sequel.

4*b*. *The Outer and Inner Bands.*

The division into an outer and an inner band is well seen in *T. Murchisoni*, *T. fimbriatus*, *T. hibernicus*, *T. Bucklandi*, *T. seticornis*, *T. Nicholsoni*, and *T. subradiatus*.

The two portions or bands are separated as a rule not only by an angular junction but also by the marked enlargement or thickening of the concentric ridge situated along this line. This specially developed ridge may be termed for convenience the 'girder', as it appears to have been formed for strengthening purposes; it is particularly well seen in the British examples of *T. seticornis* and *T. Bucklandi*, but it occurs more or less strongly developed in all the species possessing an outer and inner band to the lower plate. Salter [1] briefly noticed and figured it in *T. Lloydi* and in *T. concentricus*,[2] but Nicholson and Etheridge, jun.,[3] described it as a groove instead of a ridge in the Girvan examples of *T. Bucklandi*, forming their ideas from impressions of the lower plate. Bernard Smith [4] mentioned it also as a groove in connexion with *T. Portlocki*, Salter, from Tyrone, but for the most part this structure seems to have been ignored. The author described it as a ridge in the case of *T. Nicholsoni*.[5]

4*c*. *The Position of the Girder.*

The position of the girder in relation to the concentric rows of pits on the lower surface varies to some extent in different species. In *T. Lloydi* Salter showed the girder lying inside the two outermost rows, and this is found to be the commonest position, and he described[6] also the British form of *T. concentricus* as having the girder similarly placed, i.e. between the second and third rows. This may be well seen in most Welsh examples from Bala Beds, but in those from Pwllheli the girder is not clearly differentiated, the concentric ridge between the third and fourth rows being nearly as strong as that between the second and third rows. In *T. concentricus* from the Onny River it is interesting to find the girder readily recognizable by reason of its greater strength inside the second row in the anterior median part of the fringe, but posteriorly on each side it decreases in size and is scarcely larger than the ridge inside the first row.

In *T. subradiatus*[7] the first and second concentric ridges are of equal or subequal size (though in front the ridge behind the first row is most pronounced), the girder thus not being clearly differentiated;

[1] Salter, Dec. Geol. Surv., No. vii, pl. vii, 1853.
[2] Salter, Mem. Geol. Surv., vol. iii, p. 517, pl. xix, figs. 4, 4*a*.
[3] Nicholson & Etheridge, jun., Mon. Girvan Silur. Foss., fasc. ii, p. 192, 1882.
[4] Fearnsides, Elles, & Smith, Proc. Roy. Irish Acad., vol. xxvi, sect. B, No. 9, p. 122, 1907.
[5] Reed, Geol. Mag., Dec. V, Vol. VII, p. 212, 1910.
[6] Salter, Mem. Geol. Surv., vol. iii, p. 517, pl. xix, figs. 4, 4*a*.
[7] Reed, Mon. Girvan Trilob. (Palæont. Soc.), pt. i, p. 12, pl. ii, figs. 2, 5, 6.

but as the inner plate bends up immediately behind the second ridge it is probable that this one represents the girder of other species.

In the allied species *T. ornatus* and *T. Goldfussi* from Bohemia there is seen to be no distinguishable girder, the ridges being equal and the lamella not bent, as Barrande figured.[1]

In *T. Nicholsoni*[2] the girder is strongly developed inside the second row (Pl. XVIII, Fig. 6), and the same position is found in specimens of *T. seticornis* from Rhiwlas, Norber Brow, Applethwaite, Sholeshook, Redhill, etc.

In *T. Bucklandi* from Girvan the girder is equally well developed, and has the same position, but this is not the case in immature individuals in front where only one row of pits is present (see sequel). The same peculiarity is noticeable in specimens of *T. seticornis* from the *Trinucleus* Shales of Nitsjo, Dalarne.

In *T. Murchisoni* there is a well-marked girder inside the series of radial grooves on the outer band, each of which holds three pits in a line (Pl. XVIII, Fig. 11). It is similarly situated, but narrower, in *T. Etheridgei*.

The position of the girder inside the first concentric row is found in *T. Portlocki* from Tyrone, as is well shown in B. Smith's figure,[3] and the type-specimen of Portlock's *T. elongatus*[4] likewise has the girder in the same position.

T. favus, Salter, has the strongest of its concentric ridges inside the first row (Pl. XVIII, Fig. 9), and the same is noticeable in American specimens of *T. concentricus* from the Utica Slate.

In *T. fimbriatus* the lower surface of the fringe (Pl. XVIII, Fig. 10), which is quite unlike the upper one in the character of its pitting (see sequel), has a broad outer band with only one marginal row of pits and no radial grooves; inside this row the outer band is smooth and devoid of pits to the line of bending, which is sharp but not marked by any thickening or distinct girder.

T. hibernicus has a somewhat similar wide smooth flat space on the outer band behind the two rows of small sunken radially arranged pits in weak sulci (Pl. XVIII, Fig. 2); the junction with the inner band is likewise angulated and sharply defined, but without any raised ridge or thickening.

EXPLANATION OF PLATE XVIII.

FIG. 1. *Trinucleus concentricus* (Eaton). Middle Bala: Onny River, Shropshire. Impression of part of upper lamella of fringe. × 6.

,, 1*a*. Ditto. Diagrammatic section of upper and lower lamellæ, showing canals between opposite pits.

,, 1*b*. Ditto. Natural section across fringe, showing interlamellar space, with connecting 'pillars' formed by union of opposite pits. × 6.

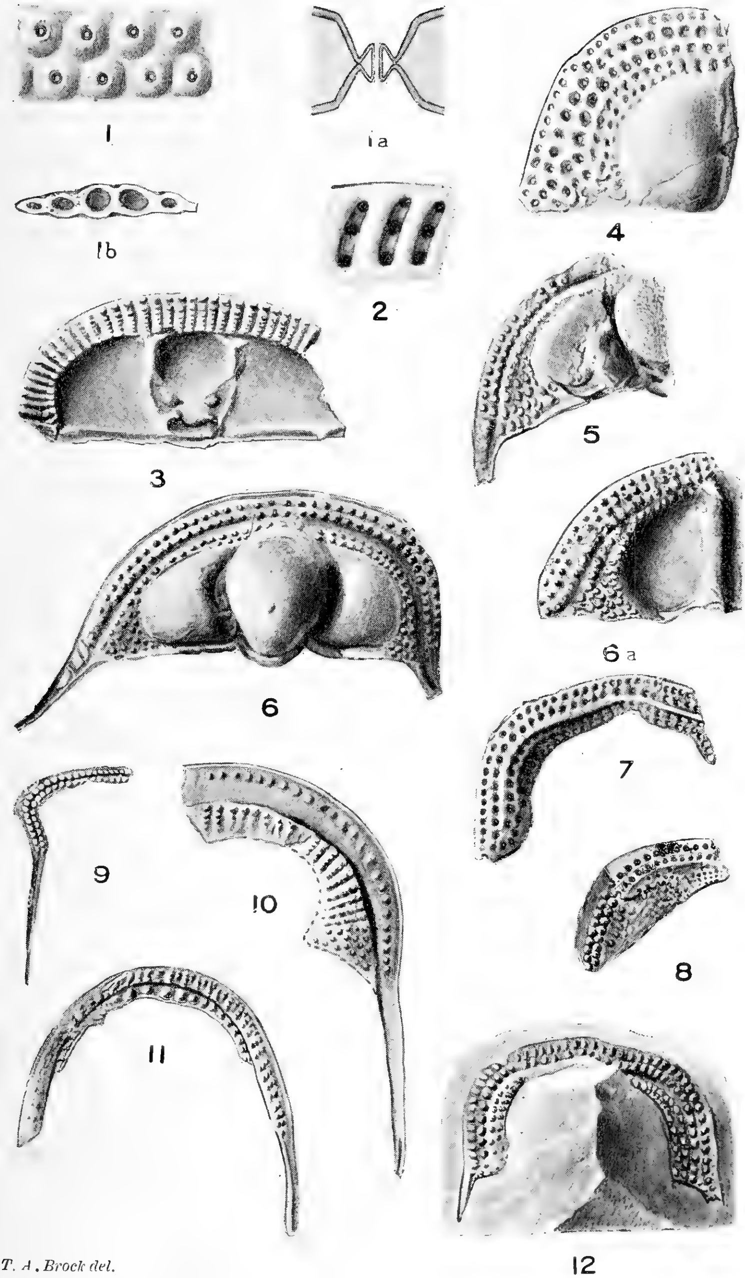
,, 2. *T. hibernicus*, Reed. Tramore Limestones: Tramore, co. Waterford. Portion of upper surface of fringe, showing pits fused and sunk in radial sulci. × 6.

[1] Barrande, Syst. Silur. Bohême, vol. i, pls. xxix, xxx.

[2] Reed, GEOL. MAG., Dec. V, Vol. VII, p. 212, Pl. XVI, 1910.

[3] Fearnsides, Elles, & Smith, Proc. Roy. Irish Acad., vol. xxvi, sect. B, No. 9, p. 121, pl. viii, fig. 1, 1907.

[4] Portlock, Geol. Rep. Londond., p. 263, pl. IB, fig. 6.



T. A. Brock del.

British Ordovician species of *Trinucleus*.

FIG. 3. *T. fimbriatus*, Murchison. Llandeilo: Gwernyfedfach, Builth. Impression of upper surface of fringe, showing pits in radial grooves. × 2½.

,, 4. *T. concentricus* (Eaton). Middle Bala: Cheney Longville. Portion of upper surface of fringe, showing increase in number of pits of first row by intercalation. × 2½.

,, 5. *T. seticornis* (Hisinger). Coniston Limestone Series: Applethwaite Common. Impression of portion of lower surface of fringe, showing 'girder' and increase in number of rows on outer band by fission of pits. × 2½.

,, 6. *T. Nicholsoni*, Reed. Dufton Shales: near Melmerby. Impression of lower surface of fringe, showing girder, etc. × 2½.

,, 6*a*. Ditto. Impression of upper surface of fringe, showing radial arrangement of pits. × 2½.

,, 7. *T. concentricus* (Eaton). Middle Bala: Onny River. Lower surface of fringe, showing girder feebly differentiated in median portion, and intercalation of pits in outermost row. × 2½.

,, 8. *T. subradiatus*, Reed. Balclatchie Beds: Dow Hill, Girvan. Portion of lower surface of fringe (and impression of part of upper surface), showing undifferentiated girder, etc. × 2½.

,, 9. *T. favus*, Salter. Llandeilo Beds: Meadowtown. Impression of part of lower surface of fringe, showing position of girder inside first row of pits. × 2½.

,, 10. *T. fimbriatus*, Murchison. Llandeilo: Gwernyfedfach, Builth. Impression of lower surface of fringe, showing single row of pits on outer band and radial grooves on inner band (partly restored from other specimens). × 2½.

,, 11. *T. Murchisoni*, Salter. Upper Arenig: Tasker Quarry, Shelve. Impression of lower surface of fringe, showing primary and secondary radii on outer band, girder and single row of pits on inner band in front splitting into two rows at sides. × 2½.

,, 12. *T. concentricus* (Eaton). Middle Bala: Onny River. Impression of lower surface of fringe, showing irregularity of radial arrangement. × 2½.

III.—The Cirripede '*Brachylepas cretacea*', H. Woodward.

By Thomas H. Withers, F.G.S.

(PLATE XX.)

(*Concluded from the July Number, p. 326.*)

In addition to the valves from Lüneburg herein mentioned, it has been possible to examine the more important of the material described by previous authors, namely: (1) the valve figured by H. Woodward (1868) as *Pyrgoma cretacea*, and subsequently (1901) as *Brachylepas cretacea*, now in the British Museum (Natural History), registered I. 14029; (2) the nearly complete capitulum figured as *B. cretacea* by H. Woodward (1901), in the collection of Dr. A. W. Rowe, of Margate; (3) the valve figured by Marsson (1880) as *Pollicipes cancellatus*, together with other valves studied by him, now in the Geologisches Landesmuseum of Berlin; (4) the valve figured by Quenstedt (1883) as *P. lævissimus*,[1] now in the University of Tübingen; (5) the valve mentioned by Boehm (1906), in the Geologisches Landesmuseum of Berlin; and (6) a large number of more or less

[1] I have been unable to ascertain the whereabouts of the series of valves figured as *Pollicipes lævissimus* by Zittel. Dr. E. Dacque kindly informs me that they are not in the collection of the Palæontological Museum, Munich.

broken carinæ and rostra, with several scuta and terga, obtained from the Chalk of Rügen by Mrs. Agnes Laur, and acquired by the British Museum (Natural History).

Examination of this material leaves little doubt that a single widely-distributed but variable form is represented, and young valves identical with the original of *Emarginula* (?) *Naissanti* can be seen among the valves from Rügen. The Lüneburg valves are on the whole rather less strongly ornamented than those from other countries, and this is possibly due to difference in habitat; but there is some considerable variation in the sharpness of the longitudinal and transverse ridges of the carinæ and rostra from Rügen and England.

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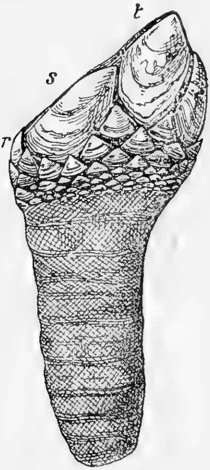

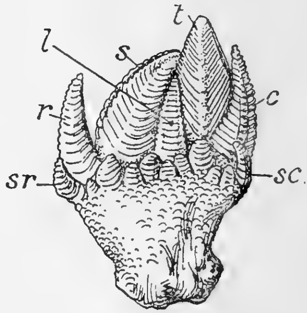

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FIG. 1. *Pollicipes polymerus*, G. B. Sowerby. Living: Upper California, Pacific, etc. (After Darwin.) Capitulum with two or more whorls of valves under the rostrum; latera gradually increasing in size towards the capitulum; peduncle generally two or three times as long as the capitulum.

,, 2. *P. mitella*, Linnæus. Living: Philippines, China, etc. (After Darwin.) Capitulum with one whorl of valves only under the rostrum; upper latera very narrow, three or four times as long as the lower latera, which overlap each other laterally; peduncle usually as long as the capitulum, but in some cases considerably shorter.

The carina and rostrum of *Brachylepas Naissanti* differ widely in shape from the same valves of *Pollicipes fallax*, now referred by H. Woodward to the genus *Brachylepas* (1906), being much more squat and semicircular, and their characteristic ornament readily distinguishes even small fragments. The scuta, terga, and upper latera of *B. Naissanti*, however, are very similar to the homologous valves of *P. fallax*. The only difference as regards the terga and upper latera, so far as one can judge from the few valves of *P. fallax* that have been examined, is that in *B. Naissanti* the transverse ridges or zones of growth are not nearly so strongly marked, and the basal portion of the terga is much more acute. The scuta of

B. Naissanti differ mainly in that, instead of having a sharp ridge with sloping sides extending from the apex to the basal angle as in *P. fallax*, there is a prominent fold which on the tergal side is abruptly folded downwards and inwards, as indicated in the transverse section (Fig. 3*a*′). The transverse ridges are not so prominent as in *P. fallax*.

In the remarkable specimen upon which Dr. H. Woodward (1901) founded the genus *Brachylepas* the more important of the valves of the capitulum are absent, and the specimen consists of the carina and rostrum, kept in position by three or four rows of imbricating plates encircling their bases. There is evidently no distinct sub-carina or sub-rostrum. Although Dr. Woodward refers in the early part of his paper to the absent valves as "the opercular valves", he subsequently says: "It seems much more probable that the scuta and terga, and perhaps a small and narrow latus, took part, as in *Pollicipes*, in building up the capitulum, the basis of which was

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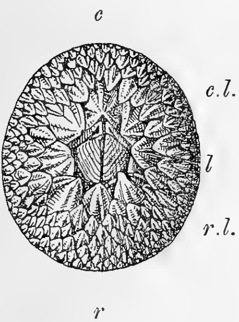

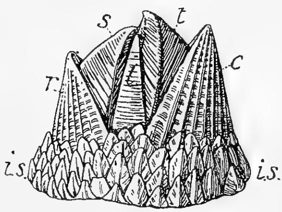

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FIG. 3. *Catophragmus polymerus*, Darwin. Living: Australian coast. (After Darwin.) Interior compartments eight, with several exterior whorls of compartments, which in old specimens number ten or even more; basis membranous.

,, 4. *Brachylepas Naissanti*, Hébert sp. Upper Senonian: England, France, Germany, etc. Restored capitulum. Capitulum comprising an upper whorl of eight valves consisting of a carina, rostrum, paired scuta, paired terga, and paired upper latera, with four whorls of imbricating valves below the rostrum; no distinct sub-carina or sub-rostrum; outer whorls of valves (probably three) possessing an inwardly projecting basal ledge, which is fixed into the median notch of the valve immediately in front of it, together forming a shelf or platform round the base of the capitulum; basis probably membranous.

This restoration is based on the valves from Lüneburg, which were found embedded together in a small piece of chalk. The number and position of the lower whorls of plates is based on the figure given by Dr. H. Woodward in his paper (1901). *r.* rostrum; *s.* scutum; *t.* tergum; *c.* carina; *l.* upper latus; *s.r.* sub-rostrum; *s.c.* sub-carina; *c.l.* carinal latus; *r.l.* rostral latus; *i.s.* imbricating plates.

protected by a series of imbricated shelly plates." He further says: "From the disparity in the proportions of the rostrum and carina and the absence of alæ, we arrive at the conclusion that the terga and scuta were not mere opercular valves, but formed a part of the capitulum."

From a study of the new material from Lüneburg, including the scuta, terga, and upper latera, it is evident that the capitulum must have been built up in the manner suggested by Dr. Woodward. The upper latera, however, are rather different, being somewhat larger and narrower than is indicated by the hypothetical figure in his restoration; they closely resemble the homologous valves of *P. fallax* and of the recent *P. mitella* (see Text-fig. 2).

We have now certain knowledge of the whole of the valves that formed the capitulum of *B. Naissanti* (see restoration, Text-fig. 4), and a comparison of the isolated valves with those of the recent *P. mitella* shows how extraordinarily alike the upper whorl of valves is in its structure and arrangement. It is especially noticeable that the upper latera are of the same type. In *B. Naissanti* the lines of growth on the inner surfaces of the carina and rostrum show that the upper part of these valves must have projected freely, the rostrum to a greater extent proportionally than the carina. The scuta and terga undoubtedly articulated together, and the greater portion of the upper latera must have overlapped the scuta and terga, since only a small triangular portion of its base appears to have been covered by the membrane (corium) lining the inside of the valves of the capitulum. In fact, the upper and main whorl of valves had precisely the same method of arrangement as in *P. mitella*. As one would naturally expect, the valves of *B. Naissanti* differ somewhat in shape from those of *P. mitella*, the most important differences being that the rostrum and carina are more squat and semicircular, approaching in this respect the sessile forms of Cirripedes, although they do not possess radii or alæ; the scuta differ mainly in having a straight basal margin. In the case of *P. mitella* (see Text-fig. 2) it will be seen that there is only one whorl of valves below the rostrum, including a sub-carina and sub-rostrum, whereas in *B. Naissanti* (see Text-fig. 4) there are at least four whorls of imbricating plates, with no sub-carina or sub-rostrum, an arrangement that reminds one of the base of the capitulum in the sessile Cirripede *Catophragmus* (see Text-fig. 3), in which old individuals have as many as ten or even more whorls of valves. The most important character of *B. Naissanti* and one of great significance, although it does not appear to have been described previously, is that the two and possibly three outermost whorls of imbricating valves have a basal ledge which projects inwards and is fixed by its somewhat acute inner extremity into a median notch at the base of the valve immediately in front of it. The valves of the innermost whorl have no such basal ledge, but have a median notch at the base, by which they are fixed externally to the projecting ledge of the surrounding whorl of valves. These basal ledges lie almost on the same plane, together forming a shelf or platform extending round the base of the capitulum. The formation of this platform seems to preclude the possibility of *B. Naissanti* having had a peduncle, and the probability is that it had a membranous basis and that the outer whorls of valves were in close proximity to the surface of attachment, as are the outer whorls of valves in the recent *Catophragmus polymerus*. Firm attachment for the membranous basis may have been afforded by the edges of the laminæ which stand out as sharp ridges on the lower surface of the basal ledges. In *C. polymerus* the outer whorls of valves are quite thin at their base, and there is a definite space bounded by the concave inner margin of each valve, the basis being membranous. Only two other species of *Catophragmus* besides *C. polymerus* have yet been discovered, namely, *C. imbricatus*, Sowerby, and *C. Darwini*, Pilsbry; the basis of *C. Darwini* is unknown, while that of *C. imbricatus* is calcareous. The basis of *B. Naissanti* was probably membranous, and in addition the basal ledges of the outer whorls of valves together formed a narrow shelf or platform round the base of the capitulum. This shelf, however, is formed by the ingrowth of the valves and by their interlocking. In the Balanidæ proper (*Balanus*) the calcareous basis is a separate part of the shell, and is added to exteriorly during the growth of the upper compartments.

Darwin[1] has already observed how nearly related *P. mitella* is to the sessile Cirripedes, and of *Catophragmus*[2] he remarked—

"This genus is very remarkable among sessile Cirripedes, from the eight normal compartments of the shell being surrounded by several whorls of supplemental compartments or scales: these are arranged symmetrically, and decrease in size but increase in number towards the circumference and basal margin. A well-preserved specimen has a very elegant appearance, like certain compound flowers, which when half open are surrounded by imbricated and graduated scales. The Chthamalinæ, in the structure of the mouth and cirri, and to a certain extent in that of the shell, fill up the interval between the Balaninæ and Lepadidæ; and *Catophragmus* forms, in a very remarkable manner, the transitional link, for it is impossible not to be struck with the resemblance of its shell with the capitulum of *Pollicipes*. In *Pollicipes*, at least in certain species, the scuta and terga are articulated together—the carina, rostrum, and three pairs of latera, making altogether eight inner valves, are considerably larger than those in the outer whorls—the arrangement of the latter, their manner of growth, and union, all are as in *Catophragmus*. If we in imagination unite some of the characters found in the different species of *Pollicipes*, and then make the peduncle so short (and it sometimes is very short in *P. mitella* [see Text-fig. 2]) that the valves of the capitulum should touch the surface of attachment, it would be impossible to point out a single external character by which the two genera in these two distinct families could be distinguished: but the more important differences in the arrangement and nature of the muscles, which are attached either to the opercular valves or surround the inside of the peduncle, would yet remain."

Whilst, as Darwin points out, the Chthamalinæ (*Catophragmus*) link up the Lepadidæ with the Balanidæ, so the fossil *B. Naissanti* presents features in common with the Lepadidæ as represented by *Pollicipes mitella*, and the Balanidæ as represented by *Catophragmus* of the sub-family Chthamalinæ. The finding of the remaining valves of the capitulum proves that the upper whorl of valves had in *B. Naissanti* precisely the same structure and arrangement as in the recent *P. mitella*, and in this respect it is allied to *Pollicipes*, although the carina and rostrum by their structure and near equality in size suggest that the animal was assuming a more sessile condition of growth. In the presence of several whorls of imbricating plates at

[1] "A Monograph on the Fossil Lepadidæ": Palæontographical Society, 1851, p. 48.

[2] "A Monograph of the Sub-class Cirripedia, the Balanidæ, etc.": Ray Society, 1854, pp. 485–6.

the base of the capitulum, *B. Naissanti* has a close outward resemblance to the sessile Cirripede *C. polymerus*, but the presence of these basal whorls of valves distinguishes it from the Balanidæ proper (*Balanus*), since they have no such basal whorls of valves. The discovery of the inwardly projecting ledge to the valves of the basal whorls in *B. Naissanti*, and their method of interlocking to form a narrow shelf or platform round the base of the capitulum, shows that these valves are quite different from those of *C. polymerus*, for in that species there is a definite space bounded by the concave inner margin of each valve. It is not quite clear from Dr. H. Woodward's paper (1901) whether he definitely regarded *B. Naissanti* as a sessile Cirripede, although he recognized its relationship to the sessile forms, but the modification of the basal whorls of valves in *B. Naissanti* to form a shelf or platform round the base of the capitulum leaves little doubt in my mind as to the sessile nature of this species.

For their kindness in loaning or procuring the loan of specimens, or for their assistance in connexion with this paper, I wish to express my indebtedness to Dr. F. A. Bather, Dr. J. Boehm, Dr. W. T. Calman, Mr. C. P. Chatwin, Dr. P. P. C. Hoek, Dr. F. v. Huene, Dr. A. W. Rowe, and Mr. C. Davies Sherborn.

EXPLANATION OF PLATE XX.

FIG.

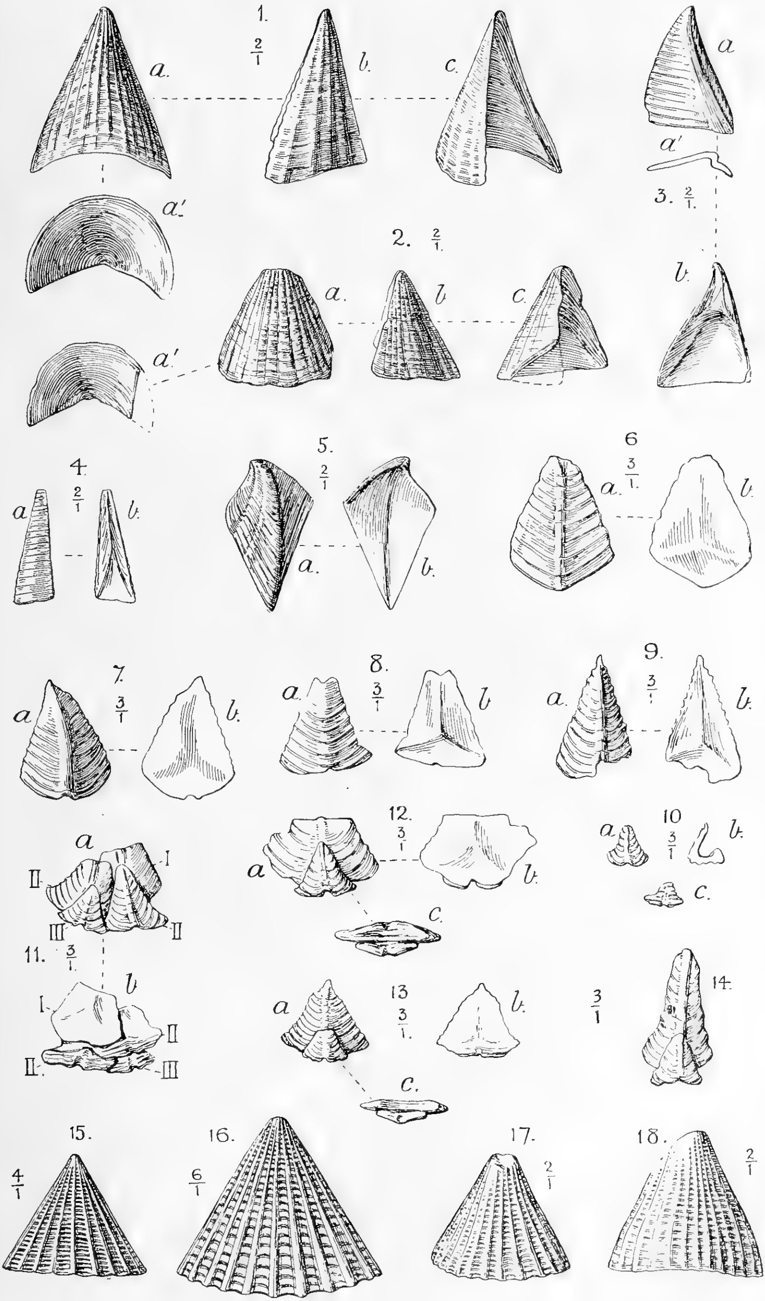
1. *Brachylepas Naissanti*, Hébert sp. Carina. *a*. outer view; *a'*. basal view; *b*. side view; *c*. inner view. Upper Senonian (*Belemnitella mucronata*-zone): Lüneburg, Hanover.
2. Id. Rostrum. *a*. outer view; *a'*. basal view; *b*. side view; *c*. inner view.
3. Id. Scutum. *a*. outer view; *a'*. transverse section; *b*. inner view.
4. Id. Upper latus. *a*. outer view; *b*. inner view.
5. Id. Tergum. *a*. outer view; *b*. inner view.
6. Id. One of the imbricating valves without a basal ledge. (Probably from a position below the upper latus.) *a*. outer view; *b*. inner view.

7–9. Id. Imbricating valves of the innermost whorl. *a*. outer view; *b*. inner view. (Fig. 7 probably occupied a position near the region of the upper latera, and Figs. 8 and 9 either at the carina or rostral end of the capitulum.)

10. Id. An imbricating valve; possibly of the second whorl; the basal ledge is wider than in most valves, and its upturned inner extremity is adapted to fix into the median notch of the valve in front of it. *a*. outer view; *b*. side view; *c*. basal view showing the ledge.
11. Id. Four of the imbricating valves still attached to one another, showing their external arrangement and the method of interlocking of the basal ledges to form the shelf or platform round the base of the capitulum. (Probably from a position below the upper latera.) *a*. outer view; *b*. inner view. I, a valve of the innermost whorl without a basal ledge; II, two valves of the second whorl with a basal ledge; III, a valve of the third whorl with a basal ledge.

12, 13. Id. Two pairs of imbricating valves, still attached to each other. (Probably of the first and second whorls.) *a*. outer view; *b*. inner view; *c*. basal view showing the basal ledge.

14. Id. Two imbricating valves still attached. Outer view. (Probably from near the region of the carina.)
15. *B. Naissanti*, Hébert sp. Carina, outer view. Upper Senonian (*B. mucronata*-zone): Meudon, France. Copy of the original figure of *Emarginula* (?) *Naissanti*, Hébert, Mém. Soc. Géol. France, 2ᵉ sér., vol. v, pl. xxix, fig. 10, 1855.



G. M. Woodward del.

Brachylepas Naissanti, Hébert sp., a Cretaceous Cirripede.

FIG.

16. *B. Naissanti*, Hébert sp. Carina, outer view. Upper Senonian (*B. mucronata*-zone): Isle of Rügen. Copy of the original figure of *Pollicipes cancellatus*, Marsson, Cirrip. d. Weiss. Schreib.-Kreide d. Rügen, 1880, pl. ii, fig. 7.
17. *B. Naissanti*, Hébert sp. Rostrum, outer view. Upper Senonian (*B. mucronata*-zone): Haldem, Westphalia. This is the valve mentioned by J. Boehm, Centralbl. f. Min., 1906, p. 449, in the Geologisches Landesmuseum of Berlin.
18. *B. Naissanti*, Hébert sp. Carina, outer view. Upper Senonian (*B. mucronata*-zone): near Norwich, Norfolk. This is the original valve figured by H. Woodward as *Pyrgoma cretacea* (GEOL. MAG., 1868, Pl. XIV, Figs. 1, 2), and as *Brachylepas cretacea* (GEOL. MAG., 1901, Pl. VIII, Figs. 3, 4; 1906, p. 337).

LIST OF WORKS CONSULTED.

BOEHM, J. "Zu *Brachylepas cretacea*, H. Woodward": Centralbl. f. Min., 1906, pp. 449–450.

DAMES, W. *Neues Jahrb.*, Bd. ii, p. 419, 1881.

DARWIN, C. R. A Monograph on the Fossil Lepadidæ, or, Pedunculated Cirripedes of Great Britain: Palæontographical Society, 4to, London, 1851, pp. vi, 88, 5 pls.

—— A Monograph on the Sub-class Cirripedia, the Balanidæ, Synopsis et Index Systematicus: Ray Society, 8vo, London, 1854, pp. 684, 30 pls.

HÉBERT, Ed. "Tableau des Fossiles de la craie de Meudon, et description de quelques espèces nouvelles": Mém. Soc. Géol. France, 2e sér., vol. v, pp. 345–74, pls. xxvii–ix, 1855.

LAHUSEN, J. I. "Fossils of the White Chalk of Simbirsk" [in Russian]: Jubilee Volume of the Imperial Russian Mining-Corps Institute, St. Petersburg, 1873, pt. ii, pp. 221–77, pls. iii–vi.

MARSSON, Th. "Die Cirripedien und Ostracoden der weissen Schreibkreide der Insel Rügen": Mitth. naturwiss. Vereine Neu-Vorpommern und Rügen, Jahrg. xii, pp. 1–50, pls. i–iii, 1880.

NILSSON, S. *Petrificata Suecana formationis Cretaceæ, descripta et iconibus illustrata.* Pars prior, Vertebrata et Mollusca sistens, 1827, pp. viii, 39, 10 pls., fol., Londini Gothorum.

QUENSTEDT, F. A. *Handbuch der Petrefaktenkunde*, 3rd ed., text and atlas, 2 vols., 8vo, Tübingen, 1882–5.

WOLLEMAN, A. "Die Fauna der Lüneburger Kreide": Abh. k. preuss. geol. Landesanst., N.F., Hft. xxxvii, pp. 129, 7 pls. and atlas, 1902.

WOODWARD, H. "First Report on the Structure and Classification of the Fossil Crustacea": Rep. Brit. Assoc. (1865), 1866, pp. 320–2.

—— "Contributions to British Fossil Crustacea": GEOL. MAG., Dec. I, Vol. V, pp. 258–61, Pl. XIV, 1868.

—— *British Museum Catalogue of British Fossil Crustacea, with their Synonyms and the Range in Time of each Genus and Order.* 8vo, London, 1877, pp. xii, 155.

—— "On '*Pyrgoma cretacea*', a Cirripede, from the Upper Chalk of Norwich and Margate": GEOL. MAG., Dec. IV, Vol. VIII, pp. 145–52, Text-figs. 1–3, Pl. VIII, Figs. 1–5, 1901. Erratum, p. 240; additional note, p. 528. [In the author's separates of this paper the words 'and Margate' have been deleted from the title, and 'Norwich' has been substituted for 'Margate' and 'Thanet' in the text. T. H. W.]

—— "Cirripedes from the Trimmingham Chalk and other localities in Norfolk": GEOL. MAG., Dec. V, Vol. III, pp. 337–53, Text-figures 1–39, 1906.

ZITTEL, K. A. *Handbuch der Palaeontologie*, Bd. ii, p. 537, 1881–5.

IV.—On the Recognition of Two Stages in the Upper Chalk.

By A. J. Jukes-Browne, F.R.S., F.G.S.

(*Concluded from the July Number, p. 313.*)

THE next step is to see if the evidence of the Echinodermata coincides with and confirms that of the Cephalopoda. The Echinoderms will be tabulated in the same way as the Cephalopoda, beginning with those of Germany. The following table has been compiled from several sources, and may not be quite complete as regards the irregular forms, though it is practically so for the Regulares, this part being taken from Schlüter's monograph on that order:—

TABLE IV.

Echinodermata in North Germany.

Species.	*Cuvieri* zone.	The *Emscher.*	Zone of *Marsupites.*	Zone of *S. binodosus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Cidaris Merceyi, Cott.	x	-	-	-	-	-
C. sceptrifera, Mant.	x	x	-	-	-	-
C. hirudo, Sorig	-	-	-	x	-	-
C. ? pistillum, Quendst.	-	-	-	-	-	x
C. pseudopistillum, Cott.	-	-	-	x	-	-
C. Herthæ, Schlüter	-	-	-	-	-	x
C. mammillata, Cott.	-	-	-	-	-	x
C. gigas, Schlüter	-	-	-	-	-	x
C. darupensis, Schlüter	-	-	-	-	-	x
C. cometes, Boll	-	-	-	-	-	x
C. striatula, v. d. Marck	-	-	-	-	-	x
C. alata, Boll	-	-	-	-	-	x
C. spinosa, Boll	-	-	-	-	-	x
C. baltica, Schlüter	-	-	-	-	-	x
C. Faujasi, Desor	-	-	-	-	-	x
C. cf. *Hardouini*, Desor	-	-	-	-	-	x
C. Gosæ, Schlüter (=*clavigera*, part)	-	-	-	x	-	-
C. vexillifera, Schlüter	-	-	-	-	-	x
Temnociderus Baylei, Cott.	-	-	-	-	-	x
T. danica, Cott.	-	-	-	-	-	x
Porocidaris lingualis, Desor	-	-	-	-	-	x
Pleurocidaris regalis, Goldf.	-	-	-	-	-	x
Salenia gehrdensis, Schlüter	-	-	-	x	-	-
S. Quendstedti, Schlüter	-	-	-	x	-	-
S. Heberti, Cott.	-	-	-	-	x	-
S. obnupta, Schlüter	-	-	-	-	-	x
S. anthophora, Müll. (=*Bonissenti*, Cott.)	-	-	-	-	-	x
S. stellifera, Hagen.	-	-	-	-	-	x
S. pygmæa, Hagen.	-	-	-	-	-	x
S. maestrichtensis, Schlüter	-	-	-	-	-	x
Peltastes heliophorus, Ag.	-	-	-	-	-	x
Cyphosoma radiatum, Sorig	x	x	x	-	-	-
C. spathuliferum, Forbes	-	x	-	-	-	-
C. gehrdense, Schlüter	-	-	-	x	-	-
C. cf. *magnificum*, Ag.	-	-	-	x	-	-
C. ornatissimum, Ag.	-	-	-	-	-	x

Species.	*Cuvieri* zone.	The Emscher.	Zone of *Marsupites.*	Zone of *S. binodosus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Cyphosoma princeps, Hagen. . . .	-	-	-	-	-	x
C. tæniatum, Hagen.	-	-	-	-	-	x
C. pseudoradiatum, Schlüter . . .	-	-	-	-	-	x
C. polygophorum, Schlüter	-	-	-	-	-	x
Echinocyphus tenuistriatus, Desor .	-	-	-	x	-	-
Zeuglopleurus pusilla, Röm. . . .	-	-	-	x	-	-
Goniopygus Heberti, Cott.	-	-	-	-	-	x
Phymechinus cretaceus, Schlüter . .	-	-	-	-	-	x
Diplotagma altum, Schlüter . . .	-	-	-	-	-	x
Catopygus obtusus, Desor	-	-	x	x	-	-
Caratomus truncatus, d'Orb. . . .	-	-	-	-	x	-
Micraster coranguinum, Leske . . .	-	x	x	-	-	-
M. cortestudinarium, Goldf. . . .	x	.	-	-	-	-
M. gibbus, Lam. (*Epiaster*)	-	-	-	x	x	x
M. glyphus, Cott.	-	-	-	-	x	x
M. Haasi, Stolley	-	-	-	-	x	-
M. Gotschei, Stolley	-	-	-	-	x	-
M. Schroderi, Stolley	-	-	-	-	x	-
Epiaster brevis, Desor	x	-	-	-	-	-
Ananchytes vulgaris, var. *conica* . .	-	-	-	-	x	x
A. vulgaris, var. *gibba*	-	x	-	-	x	-
A. vulgaris, var. *ovata*	-	-	x	x	x	x
A. vulgaris, var. *conoidea*	-	-	-	-	x	x
Galerites albogalerus, Leske . . .	-	x	-	x	-	x
G. Roemeri (=*abbreviatus*, Desor) .	-	-	-	-	-	x
Offaster pilula, Lam.	-	-	-	-	x	-
O. corculum, Goldf.	-	-	-	-	-	x
Cardiaster granulosus, Goldf. . . .	-	-	-	x	x	x
C. jugatus, Schlüter	-	-	x	-	-	-
C. Heberti, Cott. (=*maximus*, Schlüter)	-	-	-	-	x	x
Hemiaster ligeriensis, d'Orb. . . .	-	-	-	x	-	-
H. recklinghausensis, Schlüter . . .	-	-	x	-	-	-
Pygurus rostratus, Röm.	-	-	x	-	-	-
Marsupites testudinarius, Schloth. .	-	-	x	-	-	-
Uintacrinus westfalicus, Schlüter . .	-	-	x	-	-	-
Bourgeticrinus ellipticus, Müll. . .	-	-	x	x	x	-

From this table it will be seen that there are two different Echinoderm faunas in Germany, just as there are two different Cephalopodan faunas, only two species passing from the lower three to the two highest zones. There is not, however, such a clearly marked line of separation; the fauna of the *S. binodosus* zone seems from the tabulated species to be linked as closely with the higher as with the lower zones, for it contains sixteen species, of which number ten appear to be restricted to the zone and three range both up and down, while one passes downward only and two range upward. This result, however, is deceptive, because the Emscher is so poor in Echinoderms that only six species have been recorded from it, and only eight have been found in the *Marsupites* zone. If these zones were as productive in Germany as they are in England and France it is probable that the number of species ranging from them to the equivalent of the *Offaster pilula* zone would be very much larger.

In the Franco-Belgian region a much greater number of Echinoderms has been obtained from the corresponding series of beds. The following table has been compiled chiefly from the separate lists given by M. de Grossouvre in the work already mentioned, but the Belgian species have been corrected in accordance with Mr. Lambert's recent revision of them, as published in the Mém. Mus. Roy. Belg. for 1911. I have not, however, included all his new species. The Belgian occurrences are indicated by the letter B., and those in France by the letter F.; these latter include the records from Touraine and the Cotentin as well as the Paris Basin :—

TABLE V.

ECHINODERMATA OF THE UPPER CHALK IN THE NORTH OF FRANCE AND BELGIUM.

SPECIES.	Zone of *M. decipiens.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Cidaris hirudo, Sorig	x	x	x	x	x	x
C. subhirudo, Cott.	-	-	-	-	x	x
C. pseudohirudo, Cott.	-	-	-	-	-	x B.
C. sceptrifera, Mant.	x	x	x	x	x	x
C. clavigera, Koenig	x	x	x	-	x	x
C. Merceyi, Cott.	x	-	-	-	-	-
C. perlata, Sorig	x	-	-	-	-	-
C. perornata, Forbes	x	x	-	-	-	-
C. subvesiculosa, d'Orb.	x	x	-	-	-	-
C. serrifera, Forbes	x	-	-	-	-	-
C. serrata, Desor	-	-	-	x	x	x B.
C. turonensis, Gauthier	-	x	x	-	-	-
C. Faujasi, Desor	-	-	-	-	-	x B.
C. Hardouini, Desor	-	-	-	-	-	B.
C. lingualis, Desor (*Porocidaris*)	-	-	-	-	-	B.
Cyphosoma radiatum, Sorig	x	x	-	x	x	x B.
C. granulosum, Goldf.	-	x	-	-	-	x
C. corollare, Agas.	-	x	-	-	-	B.
C. magnificum, Cott.	-	x	x	-	-	-
C. Koenigi, Mant.	-	x	x	x	B.	-
C. Delaunayi, Cott.	-	-	x	-	-	-
C. Corneti, Cott.	-	-	-	-	-	B.
C. elongatum, Cott.	-	-	·	x	x	x
C. remus, Cott.	-	x	-	-	-	-
C. spathuliferum, Forbes	-	-	-	-	-	B.
Salenia incrustata, Cott.	-	x	-	x	x	-
S. Bourgeoisi, Cott.	-	x	x	-	-	-
S. geometrica, Ag.	-	x	x	-	-	-
S. anthophora, Müller	-	-	-	B.	B.	-
S. Janeti, Cott.	-	-	-	-	-	x
S. Bonissenti, Cott.	-	-	-	-	-	x
S. Heberti, Cott.	-	-	-	-	x	-
S. maestrichtensis, Schlüter	-	-	-	-	-	x B.
Peltastes heliophorus, Cott.	-	-	-	-	-	x B.

Species.	Zone of *M. decipiens.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Pyrina Bourgeoisi, Cott.	-	-	x	-	-	-
P. ovulum, Lam.	-	-	x	-	-	-
Nucleolites analis, Ag.	-	-	-	-	-	F., B.
N. minimus, Ag.	-	-	x	-	-	-
N. coravium, Ag.	-	-	-	-	-	F., B.
Echinobrissus Guillieri, Cott.	x	-	-	-	-	-
Catopygus elongatus, Desor	-	-	x	-	-	B.
C. fenestratus, Ag.	-	-	-	-	B.	B.
Oolopygus Orbignyi, Cott.	-	-	-	-	-	x
O. pyriformis, Ag.	-	-	-	-	B.	B.
Trematopygus oblongus, Desor	-		x		-	-
Hemiaster nasutulus, Sorig	x	-	-	-	-	-
H. nucleus, Desor	x	-	-	-	-	-
H. ligeriensis, d'Orb.	-	-	x	-	-	-
H. angustipneustes, Desor	-	x	x	-	-	-
H. prunella, Lam.	-	-	-	-	-	F., B.
H. Neustriæ, Desor	-	-	-	-	-	F.
Linthia spiennesensis, Schlüter	-	-	-	-	-	B.
Cassidulus lapiscancri, Lam.	-	-	-	-	-	F., B.
C. elongatus, d'Orb.	-	-	-	-	-	B.
C. Peroni, Gautier	x	-	-	-	-	-
Clypeolampas ovum, Ag.	-	-	-	-	-	B.
Heteropneustes tenuiporus, Cott.	-	-	x	-	-	-
Caratomus avellana, Dubois	-	-	-	-	-	F., B.
C. ocellatus, Cott.	-	-	-	-	-	B.
C. hemisphericus	-	-	-	-	-	B.
C. peltiformis, Wahl.	-	-	-	-	-	B.
C. sulcatoradiatus, Desor	-	-	-	-	B.	B.
Hemipneustes ocellatus, Cott.	-	-	-	-	-	B.
H. striatoradiatus, d'Orb.	-	-	-	-	-	B.
Rhynchopygus Marmini, d'Orb.	-	-	-	-	-	F., B.
Faujasia Faujasi, d'Orb.	-	-	-	-	-	B.
F. Delaunayi, d'Orb.	-	x	-	-	-	-
Peroniaster Cotteaui, Gauthier	-	-	-	-	x	-
Cardiaster granulosus, Goldf.	x	x	-	x	B.	F., B.
C. Heberti, Cott. (=*maximus*, Schl.).	-	-	-	-	-	F., B.
Plesiaster bucardium, Goldf.	-	-	-	-	-	B.
Galerites albogalerus, Klein	-	x	x	x	x	-
G. circularis, Buc.	-	x	x	-	-	-
G. sulcatoradiatus, Goldf.	-	-	-	-	-	B.
Echinocorys scutatus, var. *gibba*	x	x	-	-	-	B.
E. scutatus, var. *striata*	-	x	x	x	x	x B.
E. scutatus, var. *conica*	-	x	x	x	x	x B.
E. scutatus, var. *meudonensis*	-	-	-	-	-	x B.
E. orbis, Arnaud	-	-	-	-	-	x B.
Holaster placenta, Ag.	x	-	-	-	-	-
Offaster pilula, Lam.	-	-	x	x	x	x B.
O. Gauthieri, Lamb.	-	-	-	-	-	x
Orthopsis miliaris, d'Arch.	-	-	x	-	-	-
Holectypus turonensis, Desor	-	-	x	-	-	-
Epiaster brevis, Schlüter	x	-	-	-	-	-
E. gibbus, Schlüter	-	x	x	-	-	-
Micraster decipiens, Bayle	x	-	-	-	-	-

Species.	Zone of *M. decipiens.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Micraster turonensis, Bayle	-	x	-	-	-	-
M. senonensis, Lamb.	x	x	-	-	-	-
M. senonensis, var. *belgica*, Lamb.	-	-	-	B.	-	-
M. icaunensis, Lamb.	x	-	-	-	-	-
M. Cayeuxi, Parent	x	x	-	-	-	-
M. coranguinum, Leske	-	x	x	B.	B.	-
M. gibbus, Lam., var. *fastigatus*	.	-	-	x	-	-
M. gibbus, Lam., var. *Stolleyi*	-	-	-	-	B.	B.
M. Brongniarti, Hébert	-	-	-	-	-	F., B.
M. Schroderi, Stolley	-	-	-	-	x B.	F., B.
M. regularis, Arnaud	-	-	-	-	x	F.
M. ciplyensis, Schlüter	-	-	-	-	-	B.
Leucaster remensis, Gauthier	-	-	-	-	x	-
Marsupites testudinarius, Schloth.	-	-	x	-	-	-
Uintacrinus westfalicus, Schlüter	-	-	x	-	-	-
Bourgeticrinus ellipticus, Müll.	x	x	x	x	x	-

In considering this table, if in the first place we leave the *Offaster* zone out of account we find that the three lower zones have yielded forty-eight species and that the two higher zones contain no fewer than fifty-six species. Of this large number only ten species and varieties are common to the two assemblages, which are thus very different, though, as might be expected, they are not so entirely distinct as those of the more highly organized Cephalopoda.

The line of division between the two stages is not, however, so clearly indicated by the Echinoderms, for the fauna of the *Offaster* zone seems to form a complete passage from the one to the other. This zone has yielded fifteen species, of which ten range both up and down, one ranges downward only, three range up but not down, and one is restricted to the zone. The fact is that the tabulated number of occurrences is hardly sufficient to give a reliable result, and we can only infer that the zone might be placed in either stage.

In passing to the South of France we come to a different area of deposition, inhabited by an assemblage of Echinoderms which differed considerably from that of the Anglo-Parisian basin. Some of the northern species do occur in it, but there are a large number of others. From the lists given by M. de Grossouvre, in the work already mentioned, I have compiled a table of the distribution of species in the Aquitanian and Pyrenean areas, in order to ascertain what evidence they afford. This list includes no fewer than one hundred species, and yet is probably not quite complete; the greater number (sixty-three species) occur in the two higher zones and only ten of these range down into the three lower zones. The equivalent of the *Offaster* zone has yielded twenty-four species, and of these ten range both upward and downward, three range down only, and six pass up, while five are restricted. Here again, therefore, the existence of two different faunas and consequently of two distinct stages is very apparent, but there is a transition from one Echinoderm fauna to the other, and the zone might be placed in either stage.

Lastly, Table VI shows the distribution of the Echinoids and Crinoids through the same zones in England, and in compiling this I have received special assistance from Mr. A. W. Rowe, who has kindly sent me notes regarding the identification and range of all the species, so that this list is more correct than any that has previously been published.

In comparing this with the preceding lists it will be noticed that the number of species is less and that the proportion of them which ranges from the lower to the higher zones is greater. Both these peculiarities are doubtless owing to the fact that in England there is little variation in the lithological character of the Upper Chalk, the whole of it being a deep-water facies of the formation deposited under conditions which did not change greatly from beginning to end. There was, therefore, no sudden or rapid extinction of species, only the increasing rarity of some and the occasional introduction of new forms.

In spite of these conditions there are many species which do not range from the lower to the higher zones. The total number of species and varieties enumerated is fifty-one, and of these forty-four occur in the lower four zones and twenty-five in the two higher zones, nineteen species being common to the two assemblages. This is less than half of the larger fauna, so that there is still a considerable difference between them. The zone of *O. pilula* has yielded twenty-seven species, of which seventeen range both up and down, only two have an exclusively upward range, while eight do not range higher; it is therefore more closely connected with the lower than the higher zones.

TABLE VI.

ECHINODERMS IN ENGLAND.

SPECIES.	Zone of *M. cortestudinarium.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Cidaris hirudo, Sorig	x	x	x	x	x	x
C. sceptrifera, Mant.	x	x	x	x	-	-
C. clavigera, Koenig	x	x	x	-	-	-
C. perornata, Forbes	x	x	x	x	-	-
C. subvesiculosa, d'Orb.	x	x	x	x	x	x
C. Merceyi, Cotteau	x	x	-	-	-	-
C. serrifera, Forbes	x	x	-	-	-	-
C. serrata, Desor	-	-	-	-	-	x
C. pleracantha, Ag.	-	x	-	x	x	x
Cyphosoma Koenigi, Mant.	x	x	x	x	-	x
C. corollare, Ag.	-	x	x	x	x	x
C. granulosum, Goldf.	x	-	-	-	-	-
C. magnificum, Cott.	-	-	-	x	x	x
C. elongatum, Cott.	-	-	x	-	-	-
C. radiatum, Sorig	x	x	x ?	-	-	-
C. spatuliferum, Forbes	x	x	x	x	-	-

Species.	Zone of *M. cortestudinarium.*	Zone of *M. coranguinum*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Salenia granulosa, Forbes	x	x	x	x	x	x
S. geometrica, Ag.	-	-	x	x	x	x
S. magnifica, Wright	-	-	-	-	x	x
Zeuglopleurus Rowei, Gregory	-	-	x	-	-	-
Helicodiadema fragile, Wilt.	-	x	x	x	x	x
Echinocorys scutatus, Leske (*ovata*)	-	x	x	x	x	x
E. scutatus, a gibbous form	-	-	x	x	-	-
E. scutatus, var. *gibba*, Lam.	x	-	-	-	x	-
E. scutatus, var. *depressa*, Bryd.	-	x	x	x	-	-
E. scutatus, var. *pyramidata*, Bryd.	-	-	x	x	-	-
E. scutatus, var. *subconica*, Bryd.	-	-	-	-	-	x
Galerites albogalerus, Leske	x	x	x	x	-	x
G. albogalerus, var. *globulus*, Desor	-	x	x	-	-	-
Cardiaster ananchytis, Goldf.	-	x	x	x	-	x
C. Cotteauanus, Schlüter	x	-	-	-	-	-
Offaster pilula, Lam. (type)	-	-	x	x	x	x
O. pilula (dwarf var.)	-	-	-	-	x	x
Holaster planus, Mant.	x	-	-	-	-	-
H. placenta, Ag.	x	x	x	x	-	-
Micraster cortestudinarium, Goldf.	x	-	-	-	-	-
M. præcursor, Rowe	x	x	-	-	-	-
M. coranguinum, Leske	-	x	x	x	x	-
M. glyphus, Cott.	-	-	-	-	x	x
Epiaster gibbus, Lam.	x	x	x	-	-	x
Infulaster excentricus, Bosc.	x	x	x	-	-	-
I. rostratus, Forbes	-	x	x	x	x	-
Hemiaster minimus, Ag.	x	x	x	x	x	x
Marsupites testudinarius, Schloth.	-	-	x	-	-	-
Uintacrinus westfalicus, Schlüter	-	-	x	-	-	-
Pentacrinus Bronni, Hagenow	-	-	-	-	-	x
P. Agassizi, Hagenow	x	-	-	-	-	-
Isocrinus Kloedeni, Hagenow	-	x	x	x	-	-
Bourgeticrinus ellipticus, Müller	x	x	x	x	x	x
Ophiura serrata, Römer	-	x	x	x	-	-
Roveacrinus communis, Douglas	x	x	x	x	-	x

Another group of fossils which furnishes useful evidence of the distinctness of the two faunas is the genus *Inoceramus*. This was studied by Schlüter in Germany in 1876,[1] and a tabular view of this zonal distribution in that country is given at the end of his monograph. Recently the genus has been more thoroughly investigated, so far as the British species are concerned, by Mr. H. Woods, whose excellent monograph will henceforward be the chief book of reference for the European species generally.

The species which occur in France, Germany, and other countries now require re-examination in the light of Mr. Woods' researches and studies of the various type-specimens, but by the aid of some notes on foreign forms in Mr. Woods' monograph, I have been able to compile a list of those which occur in the Paris Basin.

[1] *Palæontographica*, Bd. xxiv, 1876–7.

The following tables, showing the zonal distribution of the species of *Inocerami*, have thus been prepared from the sources above mentioned, that for North Germany being taken from Schlüter, with some corrections and modifications :—

TABLE VII.

INOCERAMI IN THE UPPER CHALK OF ENGLAND.

SPECIES.	Zone of *M. cortestudinarium.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Inoceramus Lamarcki, Park. (type) (= *I. Brongniarti*, Mant.)	x	x	-	-	-	-
I. Lamarcki, var. *Cuvieri*, Sow. . .	x	x	-	-	-	-
I. Lamarcki, var. *Websteri*, Mant. .	x	-	-	-	-	-
I. Lamarcki, var. *undulatus*, Mant. .	x	-	-	-	-	-
I. cordiformis, Sow.	x	x	x	-	-	-
I. involutus, Sow.	x	x	-	-	-	-
I. inconstans, Woods	x	x	x	x	x	x
I. inconstans, var. *striatus*, Mant. .	?	x	-	-	-	-
I. inconstans, var. *sarumensis*, Woods	-	-	-	x	-	-
I. digitatus, Sow.	-	x	-	-	-	-
I. undulato-plicatus, Römer . . .	-	x	-	-	-	-
I. undulato-plicatus, var. *digitatus*, Sch.	-	x	-	x	-	-
I. cardissoides, Goldf.	-	-	?	x	-	-
I. subcardissoides, Schlüter	-	?	-	-	-	-
I. pinniformis, Will.	-	-	-	x	-	-
I. balticus, Bohm	-	-	x	x	x	x
I. lingua, Goldf.	-	-	x	x	?	x
I. lobatus, Goldf.	-	-	x	x	-	-
I. tuberculatus, Woods	-	-	-	x	-	-

TABLE VIII.

INOCERAMI IN THE UPPER CHALK OF NORTH GERMANY.

SPECIES.	*Cuvieri* zone.	The *Emscher.*	Zone of *Marsupites.*	Zone of *S. binodosus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Inoceramus Lamarcki, Park. (= *Brongniarti*, Schlüter, etc.)	x	-	-	-	-	-
I. Lamarcki, var. *Cuvieri*, Sow. . .	x	x	-	-	-	-
I. involutus, Sow.	-	x	-	-	-	-
I. involutus, var. *exogyroides*, Meek .	-	x	-	-	-	-
I. involutus, var. *umbonatus*, Meek .	-	x	-	-	-	-
I. digitatus, Sow.	-	x	-	-	-	-
I. subcardissoides, Schlüter	-	x	-	-	-	-
I. unduloplicatus, Schlüter	-	x	-	-	-	-
I. radians, Schlüter	-	x	-	-	-	-
I. subquadratus, Schlüter	-	x	-	-	-	-
I. gibbosus, Schlüter	-	x	-	-	-	-
I. cardissoides, Goldf.	-	?	x	-	-	-
I. cancellatus, Goldf.	-	-	x	x	-	-
I. balticus, Bohm (= *Crippsi*, auct.) .	-	-	x	x	x	x
I. lingua, Goldf.	-	-	x	x	-	-
I. lobatus, Goldf.	-	-	x	x	-	-

TABLE IX.

Inocerami in the Upper Chalk of the Paris Basin.

Species.	Zone of *M. decipiens.*	Zone of *M. coranguinum.*	Zone of *Marsupites.*	Zone of *O. pilula* and *A. granulatus.*	Zone of *A. quadratus.*	Zone of *B. mucronata.*
Inoceramus Lamarcki, Park. (type) .	x	x	-	-	-	-
I. Lamarcki, var. *Cuvieri*, Sow. . .	x	x	-	-	-	-
I. Lamarcki, var. *Mantelli*, de Mercey	x	x	-	-	-	-
I. Lamarcki, var. *undulatus*, Sow. .	x	-	-	-	-	-
I. inconstans, Woods (=*Brongniarti*).	x	-	-	-	-	-
I. involutus, Sow.	x	x	-	-	-	-
I. digitatus, Sow.	-	x	-	-	-	-
I. lezennensis, Decocq	-	x	-	-	-	-
I. inæquivalvis, Schlüter	x	-	-	-	-	-
I. unduloplicatus, Röm.	-	x	-	-	-	-
I. subcardissoides, Schlüter	-	x	-	-	-	-
I. balticus (=*Crippsi*, auct.) . . .	-	-	-	-	x	x
I. lingua, Goldf.	-	-	?	-	-	-

From these lists it will be seen that the English list is the most complete, and that the evidence of the *Inocerami* accords entirely with that of the Cephalopoda. The zone of *Offaster pilula* in England has yielded nine species, of which five, and probably six, range downward, while only three of them range upward. In Germany the same zone has yielded four species, all of which range down into the *Marsupites* zone and only one (*balticus*) passes up into the higher zones.

Inferences.

Reviewing the results which have been obtained from the tabulated distribution of Cephalopoda, Echinoderms, and *Inocerami* in the Upper Chalk, we arrive at the following conclusions:—

1. That the Upper Chalk, with its equivalent in France and Germany, contains two distinct assemblages or faunas, and consequently that it comprises two stages as distinct from one another as are the Albian, Cenomanian, and Turonian.

2. That the evidence of the Cephalopoda fixes the line of division between the zones of *Offaster pilula* and *Actinocamax quadratus.*

3. That the distribution of *Inocerami* in all three countries leads to the same conclusion as that of the Cephalopoda.

4. That the evidence of the Echinoderms is less definite, because the assemblage found in the *O. pilula* zone is everywhere a passage fauna with many species that range both up and down.

The exact position of the boundary-plane between the two stages is of course a mere matter of detail. The important point, which is so obvious from an inspection of the preceding tables, is the recognition of the fact that our Upper Chalk is not a single stage comparable with the Middle Chalk or Turonian, but comprises two such stages for which names must be adopted.

With regard to the plane of division between them, the weight of evidence indicates that it should be drawn at the top of the zone of *Offaster pilula* and *Scaphites binodosus.* This line seems to be clear enough in Germany, but has not yet been accurately determined in England or France.

NOMENCLATURE.

Having demonstrated the existence of two different faunas, and consequently of two different stages, in what we have hitherto been accustomed to call the Upper Chalk, it becomes necessary to consider by what names they should be called. The old-fashioned names Lower Middle and Upper Chalk may still be used for divisions which can be shown on geological maps, because they have usually well-marked lithological boundaries, but we cannot continue to employ them as stage-names, since the Chalk is really divisible into four stages, not three as was formerly supposed.

There can be little doubt that we must adopt the French method of nomenclature, and it will also be convenient to employ the actual French names for these stages as far as possible, because these names are in general use on the Continent. Unfortunately, however, the French geologists are not yet agreed on the question of simplifying their nomenclature and making it accord with the stratigraphical value of their divisions.

The French terminology originated with d'Orbigny in 1843, and at first he only recognized two divisions or stages in the Chalk, giving these the names of *Turonien* and *Sénonien.* Subsequently he became aware that his Turonien included two distinct faunas and also that there was another fauna above his Sénonien in Denmark. Consequently in 1852 he established four stages under the names of *Cénomanien*, *Turonien*, *Sénonien*, and *Danien.* These names have been in use ever since that date, and the definitions of them given by d'Orbigny in his *Géologie Stratigraphique* of 1852 show that the first three correspond very closely with our Lower, Middle, and Upper Chalk.

As time went on, however, French geologists found that the Senonian was divisible into two or more parts, which they regarded as stages or sub-stages. Thus the Senonian of the Paris Basin was divided by Lambert in 1876 into Lower and Upper divisions, while that of Aquitaine was divided by Coquand into four parts, to which he gave the names of *Coniacien*, *Santonien*, *Campanien*, and *Dordonien.*[1]

In 1879 de Mercey pointed out that there were really only two separate stages in the Senonian of d'Orbigny, but that these ought to be recognized and that one of them should receive a new name while Senonian was retained for the other; just as d'Orbigny himself had given a new name to part of his original Turonian, but retained that name for a restricted Turonian. De Mercey advocated the retention of the name Senonian for the upper part and the adoption of Coquand's name Santonian for the lower part.[2]

The correlation of the successive zones was not, however, fully established in 1879. Coquand's stages were really sub-stages, but they

[1] Coquand, Bull. Soc. géol. France, ser. II, t. xiv, p. 746, 1857.
[2] Bull. Soc. géol. France, ser. III, t. vii, p. 355, 1879.

were definite stratigraphical units, and de Mercey was wrong in supposing that the *Coniacien* had no separate existence. The *Santonien* was not therefore the equivalent of the whole "Sénonien Inférieur" as he supposed. Moreover, French geologists were so accustomed to the use of the name Senonian in its wider and more comprehensive application that the idea of its restriction to a portion of the original stage did not commend itself to them. Hence a complicated system of stages and sub-stages was adopted, which included an unnecessary number of names and could not possibly be used with advantage in any other country. The following table shows the divisions recognized by de Grossouvre in 1901 :—[1]

Stages.	Sub-stages.	Assises.
Danien		
Sénonien	Campanien	Supérieur. Inférieur.
	Corbiérien	Santonien. Coniacien.
Turonien	Angoumien Saumurien	
Cénomanian . .	(not divided).	

It is obvious that this scheme is illogical; the Corbiérien and Campanien have the same palæontological and stratigraphical value as the Turonian, and consequently the retention of a comprehensive Senonian can only produce confusion and misapprehension. This seems to have been perceived by de Lapparent, for in the latest edition of his *Traité de Géologie* he remarks (p. 1883) that "The old Sénonien of d'Orbigny really includes two very distinct faunas of Cephalopoda, *Mortoniceras* and *Placenticeras* prevailing in the one which is the fauna of the Emscher marls of Westphalia. The other fauna, in which *Pachydiscus* and *Baculites* are conspicuous, is that of the Chalk of Haldem and Lemberg and of the beds near Tercis. The beds which contain it form the Aturien stage, from the Adour on the banks of which this division is well developed".

De Lapparent therefore divides his Upper Cretaceous Series into six stages, for which he adopts the names Cénomanien, Turonien, Emschérien, Aturien, Danien, and Montien, thus excluding the Albien and including the Montien, which others regard as the base of the Eocene Series. The stages with which we are concerned he subdivides in the following manner :—

Stages.	Sub-stages.	Zones.
Aturien	Maestrichtien	Calcaire à *Baculites*.
	Campanien	Craie de Meudon. Craie de Reims.
Emschérien	Santonien	Craie à *Marsupites*. Craie à *M. coranguinum*.
	Coniacien	Craie à *N. cortestudinarium*.

From this it is evident that de Lapparent wished to abandon the term Senonian altogether instead of adopting the view advocated by

[1] "Recherches sur la Craie Supérieur": Mém. Carte Dét. de la France, fasc. ii, table after p. 700.

de Mercey; further, that he proposed two new stage-names when he might have adopted those used by de Grossouvre. On the other hand, it seems to me that de Mercey was right in principle and that he was quite justified in saying—"L'équité scientifique exige que les dénominations des étages de d'Orbigny subsistent dans le nomenclature, quels que soient les changements apportés dans la délimitation des étages, ou bien les démembrements opérés à leur dépens."

I am therefore strongly of opinion that the name Senonian should be used for one of these stages, and the only question is to which of them should it be applied. The name is taken from the tribe of the Senones who inhabited the country round Sens, and so far as this typical area is concerned it might be used equally well for either division, since the beds of the Lower Senonian crop out to the south-east of Sens and those of the Upper Senonian to the north-west.

We need therefore only consider to which stage the name can be most usefully and conveniently applied. Now de Grossouvre has shown that the 'Maestrichtien' is not a sub-stage, but only a part of the zone of *Pachydiscus neubergicus*, which is elsewhere included in the Campanian; in the same way its equivalent in Aquitaine (the Dordonien) is shown to be merely part of the Campanian.[1] Consequently he adopts the name *Campanian* (derived from the 'champagne' of the Charentes) to denominate the stage for which de Lapparent introduces the new name of *Aturian*. Campanian has the priority, and is now generally recognized by French geologists as a good name for this division of the Upper Chalk. There is, therefore, no need for Aturian, which should be dropped as a synonym.

On the other hand, all the names proposed for the 'Sénonien Inferieur' are open to objection. The application of Santonian to the whole stage is untenable, because the real and original Santonian was only a part of it, and Coquand was right in so regarding it. The name *Corbiérien* has not found favour in France because it is taken from a locality, Corbiéres in the Pyrenees, where the beds differ from those of the Anglo-Parisian Basin, both in their fauna and their lithological characters. '*Emschérien*' is open to the same objection, the Emscher marls being a local facies and their fauna a poor one, especially in Echinoderms, so that they do not form a suitable exemplar or type for reference.

These considerations make it clear that if the name Senonian is to be used at all it should be applied to the lower part of d'Orbigny's division, that of Campanian being adopted for the higher one. Further, there is not the slightest occasion for the use of sub-stages; a primary division of the series into stages and a subdivision of these stages into zones is all that is necessary, any kind of intermediate term is both cumbersome and useless.

In its complete development the Chalk of Northern Europe appears to be divisible into five stages, though the Danian is of smaller

[1] In both districts, however, it forms the highest portion of his zone of *P. neubergicus*, and is characterized by the presence of *Sphenodiscus Ubaghsi* and a special set of Echinoderms, so that it seems to be separable as a distinct zone.

thickness and altogether of smaller importance than the rest. The following table sets forth the names which I would adopt for these stages, and the zones which they comprise:—

STAGES.	ZONES.
DANIAN	*Nautilus danicus.*
CAMPANIAN	*Belemnitella mucronata.*
	Actinocamax quadratus.
SENONIAN	*Offaster pilula.*
	Marsupites.
	Micraster coranguinum.
	M. decipiens.
	Holaster planus.
TURONIAN	*Terebratulina lata.*
	Rhynchonella Cuvieri.
CENOMANIAN	*Holaster subglobosus.*
	Schloenbachia varians.

V.—NOTE ON THE CHALK ROCK IN NORTH KENT.

By G. E. DIBLEY, F.G.S.

IN the early spring of 1910, while collecting in the Chalk quarry at Borstal,[1] I found in a loose piece of chalk an impression of a small Gasteropod shell which probably belongs to the genus *Lampusia*. Shortly afterwards, while at the Borstal Manor Quarry, a workman brought me another small Gasteropod, which has since been identified as *Turbo geinitzi*, Woods. Both specimens were preserved as casts, showing part of the external ornament from near the apex to the basal whorl. Part of the zone of *Holaster planus* is exposed in the quarry, but the locality is not included in my previous list of exposures in the neighbourhood. The occurrence of these Gasteropods at such an horizon was almost conclusive evidence of the presence of the *Reussianum* fauna, so I again visited the quarry, in company with my wife, with a view to discovering the exact position at which these fossils occurred.

The lithological character of a certain bed of Chalk at Borstal is exactly the same as that on the other side of the Medway, being exposed in Messrs. Martin & Earl's quarry at Wickham (No. 2)[2] and at Messrs. Trechmann's quarry at Cuxton (No. 4). A small block from this bed, about the size of a cubic foot, would be found to contain irregular patches deeply iron-stained and of a nodular and fibrous character, the remainder being soft and gritty. I had for some time been familiar with its distinctive lithological features, but until that time had never succeeded in obtaining any fossils from it. A more detailed search at Wickham yielded a small indeterminable Gasteropod cast, and a specimen of *Dentalium turoniense*, Woods.

In the spring of this year we again visited the Borstal Quarry, which had been unworked since December, and during five hours' search came across the rich molluscan fauna that characterizes the 'Chalk Rock'. This was in the bed of Chalk, about 5 feet in

[1] Proc. Geol. Assoc., vol. xvi, p. 484, 1900.
[2] These numbers refer to the list of exposures in (1).

thickness, at the floor of the pit. The upper limit of the bed passes imperceptibly into the *Holaster planus* Chalk.

At Blue Bell Hill this fauna can be collected from the Chalk, one hundred yards from the summit (about 750 feet O.D.), at the sides of the path immediately opposite the church, between the school and the Windmill Inn. Most probably this bed crops out again in the large pit at the top of Blue Bell Hill (No. 10), but the face of the Chalk is too precipitous to allow of an examination.

The following is the list of fossils found in this bed. With the exception of the Echinoids and Brachiopods, most are preserved as casts, and on the whole can be determined only by the taking of gutta-percha moulds.

Heteroceras reussianum (Orb.); *Baculites bohemicus*, Fritsch; *Ptychoceras Smithi* (Woods); *Scaphites geinitzi*; *Hamites* sp. (?), Orb.; *Prionocyclus neptuni* (Geinitz); *Dentalium turoniense*, Woods; *Avellana* sp., cf. *humbolti*, Miller; *Trochus schluteri*, Woods; *Trochus berocscirense*, Woods; *Lampusia* (?) sp.; *Turbo geinitzi*, Woods; *Solariella gemmata* (Sowerby); *Trapezium trapezoidale* (Römer); *Septifer lineatus* (Sowerby); *Inoceramus costellatus*, Woods; *Inoceramus inconstans*, Woods; *Limatula* sp.; *Spondylus spinosus* (Sowerby); *Liothyrina semiglobosa* (Sowerby); *Rhynchonella limbata* (Schlotheim); *Rhynchonella plicatilis* (Sowerby); *Holaster planus*, Mantell; *Micraster præcursor*, Rowe; *Micraster leskei*, Desmoulins; *Parasmilia* sp.; *Trochocyathus* sp.; Sponges (abundant).

Mr. H. Woods[1] proposed the term 'zone of *Heteroceras reussianum*' for this assemblage, and remarked that it was not always characterized by its peculiar lithology. He mentioned Twyford, near Winchester, as a locality where the horizon can be recognized only by its fossils. In the present district also it is patent that since the Chalk Rock (*sensu str.*) is absent, the palæontological term is to be preferred for denoting this horizon. A more general use of this term as an index to the horizon is highly desirable, because, as Mr. Woods has already pointed out, the term 'Chalk Rock' is both inadequate and in some cases ambiguous. Owing to this bed being less conspicuous in its lithology than usual, it is highly probable that a detailed examination of the Chalk at this part of the *Holaster planus* zone may throw considerable light on the persistence of this zone.

We again visited the Borstal Quarry, recently, accompanied by Mr. P. Dollman, and during seven hours' work succeeded in revealing very important features after clearing a few yards of the surface. About ten feet above the floor a band of deeply iron-stained, nodular chalk is seen to be persistent throughout the quarry; these nodules are very hard and contain beautiful casts of Sponges, Lamellibranchs, Gasteropods, and Cephalopods. Immediately below the nodular band the chalk is decidedly soft, friable and somewhat gritty; but portions of the mass are very hard and not easily distinguishable by the eye from the surrounding matrix. I have obtained three beautiful examples of *Scaphites geinitzi* from this horizon, and we found *Micraster leskei* more frequently here than in any other part of the quarry.

The day previous to the visit to Borstal, we spent several hours at

[1] Q.J.G.S., vol. lii, p. 70, 1896.

Blue Bell Hill, and knowing the position of the very hard band[1] and that only a depth of about 12 feet of chalk have been removed at Borstal, explorations were made at the side of the path *downwards* as far as the West Kent Waterworks boundary-stone. As on the former visit, we obtained the characteristic fauna, including a fine cast of *Prionocyclus neptuni* (Geinitz), and also proved that a considerable thickness has to be allowed for this sub-zone.

Following up my theory on returning home, I visited Kenley (in the Caterham Valley) two evenings afterwards, and went to the Rose and Crown Quarry (32) accompanied by a friend, but finding the face of the quarry too precipitous for working we crossed the railway at the bridge and made our way about the top of the railway cutting to the commencement of the viaduct. Here we were obstructed by a thickness of nodular chalk ('hill-wash') and found that further progress was impossible. We retraced our steps by the fence which marks the railway company's boundary till we reached a spot which, by the dip of the beds, I considered to be the horizon at which this sub-zone should appear. After removing the superincumbent drift, we found remains of *Dentalium*, *Scaphites*, Gasteropod casts, and sponges in *hard white chalk* corresponding to the matrix at Borstal and Blue Bell Hill. I think that the 'finds' at this spot amply prove the truth of my previous remark that the *Reussianum* zone will be found to be persistent and must not be looked for on lithological grounds only, but on palæontological evidence.

In conclusion, I may add that I am deeply indebted to my friends Messrs. Chatwin and Withers for the great interest they have displayed in this matter and for assistance most cheerfully given.

Note. Since visiting Kenley I learn that Messrs. T. H. Withers, F.G.S., and C. P. Chatwin had already discovered this fauna in fallen blocks at the Rose and Crown Quarry and at Whyteleafe. Similar corroboration may be expected from other observers in the Chalk areas where outcrops or workings in the *Holaster planus* zone occur.

A subsequent visit to Amberley in Sussex has proved fruitful in revealing the existence of the *Reussianum* zone in the quarry outside the station.

REVIEWS.

I.—Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1911. pp. iv, 90, with 4 text-illustrations. London: printed for H.M. Stationery Office, 1912. Price 1*s*.

THIS memoir contains much of interest and importance concerning the work of the Geological Survey in various parts of Great Britain.

In the Denbighshire district work has been carried out among the Carboniferous rocks, the grouping of which in the original one-inch maps and in the memoir on the adjacent Flintshire district was

[1] The band exactly corresponding to the nodular band at Borstal has not yet been found in situ at Blue Bell Hill, but there is every reason to expect that its existence will be proved.

strongly opposed by Dr. Wheelton Hind and Mr. J. T. Stobbs (Geol. Mag. 1906). Their paper is mentioned in a footnote, but their advice does not appear to have been taken. No satisfactory evidence, however, is given for the continued classification of the strata termed Millstone Grit, nor of the Gwespyr Sandstone, etc. The red or purple marls overlying the Middle Coal-measures, and termed the Ruabon Marls, are estimated to attain a thickness of about 900 feet: of these the lower beds are worked for bricks and terra-cotta clay. The succeeding Coed-yr-allt group consists of sandstones and shales with *Spirorbis*-limestones; and the highest division, termed the Ebbistock Beds, is a thick series of red and purple sandstones with conglomeratic bands and much red marl.

In what is termed the Warwickshire district, which includes South Staffordshire, attention has been given to the Cambrian and Silurian rocks, and more particularly to the Coal-fields of South Staffordshire and North Warwickshire. In the last-named coal-field the succession is given as follows:—

Upper Red Marls and Sandstones. ('Permian' on old map.)
Upper Grey Measures. Halesowen Sandstone Series.
Lower Red Marls and Espley rocks.
Lower Grey Measures, in which alone workable coal-seams occur.

The Espley rocks are described as sometimes bright green in colour, and composed of angular chips of green shale, derived as scree material from the Cambrian Shales of Dosthill.

Breccia-beds or conglomerates with some pebbles, but mostly with angular fragments of limestone, are described as occurring above the upper part of the 'Permian' and below the Bunter pebble-beds; but there is at present considerable doubt about the grouping of these and some other Red rocks of pre-Triassic age.

In the London and South-Eastern district work has been carried on at Aylesbury and over the Chiltern Hills to Rickmansworth, and in the Bagshot areas about Ascot and Weybridge.

In Scotland the survey has been prosecuted in the West Highland district, on the gneiss and newer granites of Morvern and on the Tertiary igneous rocks of Mull; and in the North and Central Highland district among the metamorphic and associated igneous rocks of Ben Armine in East Sutherland and those of parts of Perth and Inverness. Revisions of the areas of coal-fields were made in the districts of Carluke, East Kilbride, and Douglas, and in those of Shotts and Fauldhouse. The crumpling in certain sandstones of the Millstone Grit is attributed to the decay of buried tree-trunks. In another area an illustration is given of certain 'wants' (or lack of continuity) in coal-seams adjacent to a fault; and the subject recalls to mind Dr. R. L. Jack's paper "On 'Wants' in Ironstone Seams" (Geol. Mag. 1871, p. 388).

In the record of palæontological work some interesting remarks are made on the forms of *Gryphæa* in the Lower Lias, a subject to which the late John Jones, of Gloucester, gave great attention and illustrated in quarto plates. Important records of Liassic and Oolitic fossils from Mull and from marine Upper Carboniferous beds in Central Scotland are also given. In the Appendix Dr. A. Strahan records particulars of a highly interesting boring at Ebbsfleet near Ramsgate, where Carboniferous Limestone was reached below Coal-measures (103 feet thick), at a depth of 1,159 feet.

Another article, "On Diversions of the Bourne near Chertsey," is by Mr. C. N. Bromehead; a third is on "*Orthis proava*", by Dr. E. Matley; a fourth is entitled "Notes on the Upper Limestones of the Bathgate District", Edinburgh, by Mr. M. Macgregor; and a fifth is a "Note on Fossil Plants from Garallan Pit Sinking, ½ mile S.S.W. of Old Cumnock, Ayrshire", by Dr. R. Kidston.

II.—Cambrian Geology and Palæontology. No. 6: Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata. By C. D. Walcott. Smithsonian Miscellaneous Collections, vol. lvii, No. 6 (publication 2051), 1912.

SOME beautifully preserved Crustacea form the subject of the fourth preliminary paper on the collections from the Burgess Shale, Stephen formation, British Columbia. Altogether thirty-four new species are described, ten of which belong to the Branchiopoda, and represent seven new genera and four new families. Five new genera of Malacostraca are instituted, and fourteen species are referred to them. One new family of Trilobites—the Marrellidæ—is founded for the reception of four genera and six species, all new. Of the Merostomata a new order is described, and three genera and four species are placed in it.

The shale in which these important specimens are preserved is described as being smooth, compact, exceedingly fine-grained and siliceous; the fossils are irregularly distributed, occurring in layers, and they exhibit structures that are most surprising considering their age, thus indicating very little disturbance since the rock was deposited. In some specimens traces of the alimentary canal can be observed—in the new Trilobite genus *Marrella*, for example—and in one case, in *Burgessia*, it is seen to be large where the hepatic tubes join it, and to taper to its posterior end. In this same case the hepatic cæca are beautifully preserved and have the branched structure even better than in recent Copepods.

In structure the members of this fauna are not unlike recent Crustaceans of the same orders: the stalked eyes, the antennules, and antennæ are similar, while in the thoracic appendages there are no modifications that would indicate a more primitive form. Dr. Walcott thinks it probable that in such of his new Branchiopod genera as *Opabinia* and *Burgessia* we see ancestral forms of the recent Polyartemidæ and Apodidæ, and that even in Cambrian times their great power of reproduction and their active movements enabled them to flourish "in the midst of active and powerful enemies". There is a remarkable similarity of structure in the antennæ, legs, and branchiæ of the Burgess Shale Trilobites, and those of Ordovician age, and with this new material the author now agrees with Burmeister and Bernard that the Trilobites are related more closely to the Branchiopods. The discovery of caudal rami in *Neolenus* corroborates Bernard's idea that the Trilobites came from the same stock as *Apus*. We see the commencement of the Trilobite form in *Marrella*, an *Apus*-like Crustacean, but more highly developed, and with jointed legs and fewer segments. *Marrella*, with its leg-like endopodite and expanded gill-like epipodite, is very abundant in the Burgess Shale, and has a small, strong, sub-quadrangular carapace with two postero-lateral spines and sessile eyes.

The Cambrian Crustacean fauna seems to show that five main stems (Branchiopoda, Malacostraca, Ostracoda, Trilobita, and Merostomata) started in the early Cambrian, and that all had their beginning in pre-Cambrian (Lipalian) time. Dr. Walcott thinks that more work in the Lower Cambrian will bring to light a large and varied Crustacean fauna: the occurrence of *Beltina* in the pre-Cambrian of the Rocky Mountains certainly seems to support this.

In dealing with the descent of the Cambrian Crustaceans from a "theoretical ancestral stock" (correlated with the Apodidæ) the author assumes that the Branchiopoda came first, and from these three distinct branches were developed before or during the Cambrian. The Trilobites are thought to come directly from the Branchiopods, and descent is considered to go through the Aglaspina and Limulava to the Eurypterids, and thence to the Xiphosura. The Hymenocarina and the Ostracoda are the other two lines of descent from the Branchiopods. These views are regarded only as tentative, and Dr. Walcott hopes to make a more detailed study when further material is available. The eleven plates illustrating this paper are particularly fine.

No. 8 (publication 2076) of the same volume of Smithsonian publications is a paper by the same author on "The Sardinian Cambrian genus *Olenopsis* in America". Until now the stratigraphical position of this genus in relation to the *Olenellus* and *Paradoxides* faunas has been uncertain. In the present paper Dr. Walcott describes three new species (*O.* (?) *agnesensis*, *O. americanus*, and *O. roddyi*) which give the genus a definite horizon and an extensive geographical range in North America, the new localities being in Central Pennsylvania, Montana, Alberta, and British Columbia. The horizons are Lower Cambrian and the passage beds to the Middle Cambrian. From the evidence Dr. Walcott suggests that the genotype—*O. zoppii* (Meneghini)—occurs beneath the Middle Cambrian *Paradoxides* beds in Sardinia, and as regards generic relationships he thinks that both *Olenopsis* and *Paradoxides* are descended from the *Holmia* type of the Mesodonacidæ. There is one plate, and this contains, besides figures of the new species, several photographs of *O. zoppii* from the type locality for comparison.

III.—The Origin of Earthquakes. By Charles Davison, Sc.D., F.G.S. 8vo; pp. viii, 144, with 26 text-illustrations. Cambridge: at the University Press, 1912. Price 1*s*. net.

THIS is a companion volume to that on Rocks by Professor Cole, and gives a comprehensive view of what is known about the origin of Earthquakes in language clear and concise. The author's plan is to confine his attention to the phenomena essential to any explanation of the origin of the disturbances. A study of their distribution shows that, while some earthquakes are more or less directly connected with volcanoes, active or dormant, others, including the more important and destructive, happen in districts remote from modern volcanic action. 'Destructive earthquakes occur on "the steeply sloping ocean-bed to the east of the Japanese empire. In the same way, the disastrous earthquakes of South America originate beneath the Pacific Ocean, in districts that are distant many miles from the volcanic vents of the Andean chain. The great earthquakes of India and Turkestan, again, occur in countries from which volcanic action is now entirely absent, but which lie on the steep sides of mountain ranges that are known to be of recent growth".

Earthquake shocks are of all degrees of intensity, from mere tremors to those which affect areas of nearly two million square miles, although, whether weak or strong, it is considered that, as a general rule, the centre of the disturbance is not more than a few miles below the surface.

In considering the folding and fracturing of the rocks forming the earth's crust, the author remarks that the folding would take place slowly, until it gave place to fracturing and faulting. Fractures would appear on the surfaces of folded rocks, and some earthquakes may be attributed to such causes; but it is regarded as more probable that they are caused by the abrupt and violent process of faulting. The author's principal object is "to show that the great majority of earthquakes are due to the intermittent growth of faults, that, when a displacement occurs at some depth, the friction generated by the sudden sliding of one huge rock-mass over and against the other must produce an intense jar in the solid crust around, a series of vibrations which, propagated outwards in all directions, gives rise at the surface to an earthquake shock; and that, in those somewhat rare cases in which the displacement is continued right up to the surface, the sudden spring of the displaced crust must complicate and increase the shock due to the grating of the sliding masses".

The phenomena observed in connexion with earthquakes, simple, twin and complex, in various parts of the world, the formation of fault-scarps, and other features, are duly described; and references are given to the leading publications on the subject.

IV.—Rocks and their Origins. By Grenville A. J. Cole, Professor of Geology in the Royal College of Science for Ireland. 8vo; pp. viii, 175, with 20 text-illustrations. Cambridge: at the University Press, 1912. Price 1*s*. net.

In this little volume, issued as one of "The Cambridge Manuals of Science and Literature", the author deals with the method of formation of limestones; sandstones; clays, shales, and slates; igneous and metamorphic rocks. Some attention is given to the colours of the rocks, and their soils, and more to the varied forms of scenery to which they give rise: a subject treated in most of the illustrations, among which the quartzite cone of Croagh Patrick is an example. It is needless to say that the volume is clearly and pleasantly written throughout; and the author contrives, in his limited space, to give information not only concerning the latest researches and views, but of the studies of the earlier workers among rocks, such as Cordier, Macculloch, Scrope, Ehrenberg, and Sorby. He remarks that "we are still far from discovering the primitive crust formed about a molten globe", and suggests that the "early sediments became frequently immersed in baths of molten matter, and that contact-metamorphism and admixture on a regional scale have produced in them the characters that have been attributed to a fundamental gneiss".

While the Pre-Cambrian and early Cambrian limestones may have been products of chemical precipitation, as they show no signs of organic agency, yet, as Rutley pointed out (1893), the features may be due to metamorphic influence, as in the case of the Carrara Marble. Attention is drawn to altered forms of massive limestone that have become dolomitic or phosphatic, and to the replacement of limestone by silica; here a few words might have been written on the changes into ironstone.

In treating of clays the author gives some account of Boulder-clay, remarking that "Swiss glaciers are now so limited that they are of very little use to us when we seek to explain the origin of boulder-clay"; and he appeals to the great continental glaciers of polar regions, giving also some personal observations on the minor glacial action in Spitzbergen.

The work is intended for those who are not specialists, and we may cordially commend it to junior students and general readers, while at the same time many a teacher will be glad of its helpful guidance.

V.—Geology and Physics.—The question of the depth of the zone of flow in the earth's crust is discussed by Professor Frank Adams (*Journ. Geol*, xx, p. 97, 1912). By means of experiments he has come to the conclusions that at ordinary temperatures, but under the conditions of hydrostatic pressure or cubic compression which exist within the earth's crust, granite will sustain a load of nearly 100 tons to the square inch; that under the conditions of pressure and temperature believed to obtain within the earth's crust, empty cavities may exist in granite to a depth of at least eleven miles; and that mineral veins and deposits may thus be formed to as great a depth. To the same Journal (p. 119) Mr. L. V. King contributes an article "On the Limiting Strength of Rocks under conditions of stress existing in the Earth's interior". His experiments show that no state of shearing stress in the crust of the earth, due to the weights of continents and mountains, can cause the collapse of the rock in the neighbourhood of a small cavity. It is also shown that as far as hydrostatic pressure in the earth's crust is concerned, a small cavity at ordinary temperatures will remain open, provided the depth does not exceed a value between 17·2 and 20·9 miles.

VI.—Canadian Clay and Shale Deposits.—A memoir on *The Clay and Shale Deposits of Nova Scotia and portions of New Brunswick*, by Mr. Heinrich Ries, assisted by Mr. Joseph Keele, has been issued by the Department of Mines, Canada (No. 16E, 1911). In Nova Scotia the Pre-Cambrian, Silurian, Devonian, and Triassic formations yield no materials of great value to the clay-worker, but a short account is given of a felsite quarry in the Pre-Cambrian, the material being locally called 'fire-clay'. From this rock, when crushed and mixed with clay, hard bricks can be manufactured. The important clay-bearing formations are the Lower Carboniferous, Coal-measures and Pleistocene, and some clays that may be of Cretaceous age. In New Brunswick the clay-bearing formations include Lower Carboniferous, Coal-measures, Permian, and Pleistocene. The various clay-works in both provinces are described, with notes of methods of testing the bricks. The concluding portion of the memoir contains a general account of the origin and properties of clay. Numerous illustrations of strata and brick-works are given.

VII.—Were there Climatic Zones in Devonian Time? By G. F. Matthew, D.Sc., LL.D. Trans. Roy. Soc. Canada, ser. III, vol. v, sect. iv, p. 125.

THE views of the Marquis de Saporta and other naturalists who have dealt with early climates of the earth, that there was an entire uniformity of climate in the Carboniferous and preceding ages, is controverted in this paper. The writer agrees with Naumayr and others that there was considerable diversity in these ancient climates. He sets forth the view that the Devonian plants which we know best are those of a northern range of basins. The genera *Cyclopteris* (*Archæopteris*) and *Lepidodendron* (with small areoles) are characteristic of this horizon, and are found both in Europe and America. Several areas where these plants are known are the hill region of Western New York and Northern Pennsylvania, the region of Gaspe, and the Restigondu. Areas in Europe belonging to this northern range are the Devonian of Great Britain and of Belgium, and the Upper Devonian of Bear Island in the Arctic Sea. These are contrasted with the southern range which is developed in the south-eastern part of Canada; the floras here differ from those of the northern range, and more nearly resemble those of the 'Culm' and the Coal-measures. Three principal groupings of plants are recognized in the Upper Devonian beds of this southern district; they are that of the Perry Beds, which have always been regarded as Devonian, that of Kenebecasis and Horton, which Sir William Dawson called Lower Coal-measures, and those of Riverside, etc., in Nova Scotia and Quaco in New Brunswick, which are more like the plants of the Coal-measures.

VIII.—Proceedings of the United States National Museum.

Variscite found crystallized in nodules and in irregular masses of brecciated chert near Lucin, Utah, has been examined in detail by Dr. Waldemar T. Schaller, who presents some interesting results in No. 1867 of the Proceedings (vol. xli, pp. 413–30, pl. xxxiii). Aggregates of deep-green tabular orthorhombic crystals occur, some measuring a millimetre in length. Upon heating the crystals change in colour to lavender, and their pleochroism, which before was weak, becomes very pronounced and striking. The optical properties of this mineral show some relationship to scorodite, strengite, and phosphorite. Its crystallography and chemical composition are also discussed, and a typical nodule and a crystalline aggregate, with tabular crystals, are figured on the plate.

CAMPTOSAURUS.—No. 1878 of the same volume (pp. 687–96, with plates lv–lxi) contains the description of two unusually perfect skeletons, the types of *Camptosaurus nanus*, Marsh, and *C. browni*, Gilmore, that have been mounted for exhibition in the United States National Museum. The specimens formed part of the Marsh Collection and were obtained from the well-known "Quarry 13", near Como Bluff, Albany County, Wyoming. Both stand on a base of artificial matrix representing the sandstone in which they were found, the larger (*C. browni*) being in quadrupedal position, the smaller (*C. nanus*) in bipedal pose and representing a rapidly walking animal with head thrown forward, the right leg at the end of a forward stride, and tail doubly curved and slightly lifted. Some correction of Marsh's earlier restoration has been made, and in the case of *C. browni* a better-balanced animal has been produced by the shortening of the presacral region. The mounting represents nearly the whole length of the toes (except the first) as touching the ground, on account of the fact that certain footprints show nearly the full length of the phalanges. The position in which the bones of *C. browni* were found is shown in a map, and there are also six plates reproducing photographs of the mounted skeletons.

IX.—PETROGRAPHIC METHODS. By Professor Dr. ERNST WEINSCHENK; rendered into English by R. W. CLARK. 8vo; pp. xvii + 396. New York and London: McGraw-Hill Book Company, 1912. Price 15*s*.

THE title *Petrographic Methods* includes the translation into English of two books, *Die Anleitung zum Gebrauch des Polarisations-mikroskops* and *Die Gesteinsbildenden Mineralien*. The first, on the polarizing microscope, appeared in the third edition in 1910, and the second, on the rock-forming minerals, in the second edition in 1907. Both books were then revised, and the work before us is therefore of considerable value to English students of petrology.

The necessity of a thorough knowledge of the fundamental principles of microscopic optical methods in petrology is fully realized in the first part of this book. The discussions on lenses and on polarized light are very clear, and several polarizing microscopes (chiefly by German and American makers) are described. Methods of adjustment and investigations in ordinary and in polarized light are fully dealt with. The use of accessory devices (rotation, heating, and projection) for special investigation is considered in a less detailed manner in the appendix.

In the second part 139 pages are devoted to the description of 106 rock-forming minerals; and preceding these are useful accounts of chemical and physical methods employed in separation and investigation. Eighteen tables of results at the end of this part complete this volume, which should be of great value for practical detailed work in the laboratory.

X.—Flowing Wells of Central Australia.—In an article on this subject (*Geograph. Journ.*, July and August, 1911), Professor J. W. Gregory further discusses the problem of the origin of the great underground supply of water which occurs in large part of Queensland, the north-western part of New South Wales, and the north-eastern corner of South Australia, and comes to the surface under great pressure when boreholes are put down. He argues that the flowing wells are not artesian in the ordinary sense, but are due largely to plutonic magmatic water deep-seated in origin, and brought to the surface by rock-pressure and gas-pressure produced by the heat of the water. Professor Gregory points out that there is no evidence of sufficient surface areas of intake to account for the great body of underground water from rainfall; moreover, the irregularities in the levels to which the waters rise, their periodic oscillation at non-lunar periods, the varying distribution of the saline ingredients, and high temperatures of some of the wells are pointed out in support of his view. When we consider the fluctuations in level, in temperature, and the varying amounts of saline ingredients in well-waters in Britain, the strongest argument used by Professor Gregory appears to be the inadequate areas for the percolation of rain-water. In any case the wanton waste of water from the flowing wells, to which special attention is directed, should be stopped.

XI.—Glacial Phenomena of Spitzbergen.—Mr. Lamplugh has given an interesting account, to which brief reference was made in the June Number (p. 275), of "The Shelly Moraine of the Sefström Glacier and other Spitzbergen phenomena illustrative of British Glacial conditions" (Proc. Yorks. Geol. Soc., vol. xvii, p. 216, with 13 photographic plates, 1911). While there is evidence of former glaciation over practically the whole of Spitzbergen, the extensive tracts now bare have been so eroded that most of the drifts have been removed. The presence of vast numbers of shells, mostly unbroken, in the terminal moraine of the Sefström glacier, after it had crossed an arm of the sea, shows how readily marine material can be raised from the sea-floor and transported by an advancing sheet of land-ice. The influx of land-ice does not greatly interfere with the state of adjacent land: plants and animals may continue to exist in proximity to the ice-margins. The greatest amount of drift is deposited near the limits reached by the ice. Within less than ten years a mass of Boulder-clay, 100 feet or more in thickness, was piled up by the Sefström glacier. Thickness of drift, therefore, does not necessarily indicate length of time.

XII.—A Palæozoic Fern.—Dr. D. H. Scott has given a full description with illustrations of *Zygopteris Grayi* of Williamson (*Ann. Botany*, xxvi, p. 39, 1912). He also discusses the structure and affinities of this Carboniferous fern, agreeing with Dr. P. Bertrand that it is a member of the genus *Ankyropteris*.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

June 27, 1912.—Sir Archibald Geikie, K.C.B., President, in the Chair.

"A Petrified *Williamsonia* from Scotland." By Professor A. C. Seward, F.R.S.

The species *Williamsonia scotica*, which forms the subject of this paper, is founded on a specimen from Upper Jurassic strata, probably Kimeridgian, of Eathie, near Cromarty, in the county of Ross and Cromarty, Scotland, where it was found by Hugh Miller, who published a figure and brief description of it in the *Testimony of the Rocks*. The type-specimen is in the Miller Collection, Royal Scottish Museum, Edinburgh, and it is through the courtesy of the Director that it has been possible to subject the fossil to anatomical investigation. A small piece of the type-specimen is in the Geological Department of the British Museum.

The specimen has the form of an ovate strobilus, 11 cm. long, with numerous linear bracts thickly clothed with long tubular hairs, which form a dense felt between the bracts and between the bracts and the axis of the cone. To the lower part of the peduncle are attached spirally disposed bracts embedded in a packing of hairs. The upper part of the strobilus axis, incomplete at the apex, is invested by a layer, 2 mm. broad, of relatively long and narrow appendages. Of these the great majority are interseminal scales polygonal in section, of almost uniform diameter, and ending distally in a flat truncate apex. Regularly disposed among the scales are slightly narrower and cylindrical megasporophylls, each megasporophyll being the centre of a group of from five to six interseminal scales. The megasporophylls consist of a central column of short parenchymatous cells, corresponding to the seed-peduncles in *Bennettites*, which becomes rather broader in the distal portion or nucellus composed of longer and larger cells. The nucellus of homogeneous structure is closely invested by a single integument, and this envelope overtops the conical apex as a broad micropylar tube with a slightly funnel-shaped free end, in the centre of which is a very narrow micropylar canal.

A comparison is made with *Williamsonia* and *Bennettites*, especially *B. morierei* (Sap. & Mar.), also with strobili described by Wieland as species of *Cycadeoidea*. The question of the systematic position of *Williamsonia scotica* is discussed, and the account concludes with a consideration of resemblances between the Bennettitales on the one hand and Gnetales and Ginkgoales on the other. Allusion is also made to the possible relationship of this dominant Mesozoic group to the Angiosperms.

II.—Mineralogical Society.

June 18, 1912.—Dr. A. E. H. Tutton, Vice-President, in the Chair.

T. V. Barker: The Isomorphism of the Acid Tartrates and Tartaremetics of Potassium, Rubidium, and Cæsium. The corrections of previous measurements of the three acid tartrates have been confirmed, and in addition the molecular volumes have been calculated; the properties of the three salts are found to exhibit a regular progression in order of molecular weight. Solutions of cæsium tartaremetic on evaporation yield syrups which refuse to crystallize, even when inoculated with a fragment of a salt presumably isomorphous with it. The rubidium salt, however, affords good crystals, which, contrary to previous observations, yield measurements almost identical with those of the corresponding thallium and ammonium salts, and fairly close to those of the potassium salt; there is therefore every indication that this group of salts presents relationships similar to those obtained by Tutton in the sulphate and selenate series. The eutropic character of potassium, rubidium, and cæsium compounds was discussed in detail, and it was shown that not only the cases in which they exhibit isomorphism, but also those in which isopolymorphism is met with, unmistakably point to the intermediate position of rubidium.—W. F. P. McLintock and T. C. F. Hall: On the Topaz and Beryl from the Granite of Lundy Island. The granite consists essentially of quartz, orthoclase, albite, biotite, and muscovite, cordierite and garnet also being present. Well-shaped crystals of topaz and beryl line druses in the granite, and are associated with tourmaline, fluor, and apatite. The felspar of the druses is frequently kaolinized, and the orthoclase has in every case been affected first. It is suggested that carbonic acid was the principal agent in effecting the change, and that the alkaline carbonates produced attacked the topaz, the crystals of which are invariably etched, and are sometimes altered to a white secondary mica; the formation of the fluor is ascribed to the same period.—R. H. Solly: On the Rathite Group. The characters of the members of the group were discussed, and the similarity of angles in the prism zone was pointed out.—Dr. G. T. Prior: On the Minerals of the El Nakhla el Baharia Meteorite. This meteoric stone consists of a fairly coarse-grained aggregate of green augite, a highly ferriferous brown olivine, and a little interstitial felspar. The augite, which constitutes about three-quarters of the stone by weight, has a chemical composition approximating to a formula $3\,CaSiO_3 . 3\,MgSiO_3 . 2\,FeSiO_3$, a mean refractive index 1·686, double refraction 0·035 about, and optic axial angle $2E = 89°$. The olivine closely approaches hortonolite, except that it contains no manganese; it has a chemical composition represented by the formula $2\,Fe_2SiO_4 . Mg_2SiO_4$, a mean refractive index 1·785 about, double refraction 0·050 about, and optic axial angle $2V = 87°$.—J. B. Scrivenor: Note on the occurrence of Cassiterite and Struverite in Perak. The extent of the occurrence of struverite was discussed, and specimens illustrating uncommon occurrences of tin-ore were exhibited and described.

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THE

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NEW SERIES. DECADE V. VOL. IX.

No. IX.—SEPTEMBER, 1912.

ORIGINAL ARTICLES.

SEDGWICK MUSEUM NOTES.

I.—NOTES ON THE GENUS *TRINUCLEUS*.—PART II.

By F. R. COWPER REED, M.A., F.G.S.

(PLATE XIX.)

(*Concluded from the August Number, p. 353.*)

5. *Comparison of Upper and Lower Surfaces of Head-shield.*

AS above stated, the arrangement of the pits on the lower surface of the fringe is not invariably the same as that on the upper surface, and we may now examine the degree of correspondence or difference in the better-known British species.

In *T. fimbriatus*[1] there is only a single row of pits close to the margin on the outer band of the lower surface, and they lie below the radial grooves on the upper plate, but they correspond with the outermost row of pits in these sulci only. The upper surface has all the pits arranged in radial sulci (except near the genal angles where the sulci die out), and of these 5–6 rows of pits the outermost is the largest, the others being very shallow, but increasing in size at the genal angles. The lower surface has an inner band, which bears fine radial sulci corresponding in number to the pits of the marginal row and each holding 3–4 small pits; towards the genal angles the pits do not lie in sulci. These sulci and pits have no corresponding structures on the upper surface (Pl. XIX, Figs. 2, 2*a*).

In *T. hibernicus*[2] there are no definite radial sulci on the outer band of the lower surface, but the pits in the rows are radially arranged and more or less fused in front, though at the sides they become quite separated and isolated in two distinct rows. These two rows correspond with the second and third rows on the upper surface, which has three rows of pits in front fused into short deep radial sulci; laterally these radial sulci only show two pits, and these approach one another more and more towards the genal angles till at last they fuse into one. The inner band of the lower surface has a single row of large pits corresponding in number to those of the outer band, but not represented at all on the upper surface (Pl. XIX, Figs. 1, 1*a*).

These two species show, therefore, very considerable differences in the pits of the upper and lower surfaces of the fringe.

[1] Salter, in Murchison's Silur. Syst., p. 660, pl. xxiii, fig. 2; McCoy, Syn. Pal. Foss. Woodw. Mus., p. 146, pl. iE, fig. 16.
[2] Reed, GEOL. MAG., Dec. IV, Vol. II, p. 52, Pl. III, Figs. 2–7, 1895.

T. Murchisoni[1] has the outer band of the lower surface furnished with primary radial sulci holding three pits, and shorter marginal secondary radial sulci are intercalated regularly between them and in front hold two pits but laterally only one pit. On the upper surface there is a corresponding number of primary and secondary sulci, but the primary ones hold four pits and the secondary ones two pits. These sulci on both surfaces extend right back to the genal angles. The inner band of the lower surface bears close behind the strong 'girder' in front a single concentric row of much larger pits agreeing in number and position only with the primary sulci; laterally towards the genal angles this single row splits into two rows of minute pits. It appears that the fourth or innermost row of pits in the radial sulci on the upper surface corresponds with this anteriorly single but posteriorly double row of large pits on the lower surface (Pl. XIX, Figs. 3, 3*a*).

In specimens of *T. Etheridgei*,[2] Hicks, from Scolton there is a very similar development of pits in the fringe to that in *T. Murchisoni*. The outer band of the lower surface bears in front primary radial sulci with three small pits in each, and between each pair of primary sulci there is a shorter marginal sulcus intercalated holding two pits as in *T. Murchisoni*; but laterally there is an absence of these shorter sulci, and the primary sulci nearly die out, while the pits in them become larger and more isolated. Near the genal angles a few of the shorter intercalated radial sulci reappear. On the upper surface there are similar primary and secondary radial sulci, the former holding 3–4 pits and the latter 1–2 pits. The sulci tend to die out posteriorly and the pits become more isolated, those of the first row becoming larger than the others. The short secondary radial sulci are wedged in on the margin in such a way as to seem to branch off from the side of the primaries in a Y-shaped manner, but they do not seem to originate from a true bifurcation of the primaries as Hicks' figures indicated. The inner band of the lower surface bears only one concentric row of large isolated pits fewer in number than the sulci, with a few smaller additional ones inside near the genal angles.

None of the specimens of the interesting species *T. Gibbsi*, Salter, which I have seen show the characters of the lower surface distinctly, and Salter[3] did not describe it. But as far as is known it seems to agree with the upper surface, which is wider in front than at the sides or posteriorly, and bears radial grooves holding 3–4 pits; these grooves decrease in length laterally as the fringe narrows, the pits in them being reduced to two and ultimately to one. There is only a small expansion of the fringe at the genal angles, with a few additional pores inside the main sulci.

In *T. subradiatus*[4] the pits in the two rows on the outer band of the lower surface are of equal size at the sides and alternate in the rows, but the pits are smaller in front in the second row; they are larger and deeper than those on the broad inner band, which decrease in size and depth to the inner edge. These small pits on the inner

[1] Salter, Mem. Geol. Surv., vol. iii, p. 515, pl. xiB, fig. 4.
[2] Hicks, Quart. Journ. Geol. Soc., vol. xxxi, p. 182, pl. ix, fig. 6, 1875.
[3] Salter, Mem. Geol. Surv., vol. iii, p. 516, pl. xii, fig. 10.
[4] Reed, Mon. Girvan Trilob. (Palæont. Soc.), pt. i, p. 12, pl. ii, figs. 1–6.

band are not arranged in regular concentric rows, but are placed in front in distinct radial lines with an irregular row of larger pits just inside the girder. Seven or eight pits in a line can be counted in front, but laterally they are indistinct, except along the inner edge, which shows very fine closely set shallow short radial grooves, each holding 2–3 very minute pits. The upper surface corresponds with the lower in the arrangement and development of the pits, as I have elsewhere described.

T. Lloydi, according to Salter's careful description (op. cit. supra), also appears to have the upper and lower surfaces of the fringe agreeing in their characters.

In *T. concentricus*,[1] though no strong girder is developed, there are some interesting features in the lower plate.

Two specimens of the lower plate of this species from the Utica Slate of Cincinnati show the first row of pits lying on the horizontal outer band; all the other rows lie on the concave inner band. Of these there are 2–3 concentric rows behind the first one in front of the glabella and 4–5 round the cheeks. The pits in the first row are rather smaller and more numerous than those in the second row; and the pits in all the rows alternate except in the case of the two innermost rows, the fifth row having originated by division of the fourth one and the pits therefore lying radially. On the upper surface of the fringe of this form the two outermost rows tend to be radial and also more or less fused together in front but not at the sides. This feature is also seen in a specimen from the Hudson River Group.

In British specimens attributed to *T. concentricus* we do not find always complete agreement with the above American examples, and it must be remembered that the species was first described in America by Eaton, so that the transatlantic examples must therefore be regarded as typical.

The Onny River specimens appear to approach the American somewhat closely as regards the fringe, but are not identical. A large series of examples from the Onny River have been examined, and in many cases they have the shell preserved. The upper and lower plates of the fringe are separated, as described above, and the relations of the pits on the two surfaces can thus be directly observed. On the lower plate the pits in the first row are smaller and usually about one and a half times more numerous than those in the second row, and where this is most marked all the radial arrangement is lost, but there are never any radial sulci. The pits of both the second and third rows are larger than those of the first row; those of the third row are rather smaller than those of the second row in front, but at the sides become equal.

The bending up of the inner band is well marked in front behind the second row, but with the decrease in the strength of the girder laterally the differentiation of the inner band dies out, and in section the fringe is here gently biconvex. There is a fourth row of pits alongside the cheeks, splitting into two rows at about the

[1] Eaton, Geol. Text-book, 1834, p. 34, pl. i, fig. 2.

middle, but joining up again into one near the genal angles. Occasionally a sixth row is developed inside. These three innermost rows have the pits radially arranged, but the others show no distribution into regular radial lines, being mostly alternate in successive rows.

The rows and pits in the upper plate of the fringe correspond with those on the lower, but in front of the glabella a radial alignment of the pits is often noticeable. The increase in the number of the pits in the outermost row takes place by intercalation at the sides and somewhat irregularly, so that the pits are unevenly spaced. The pits of the second and third rows are larger, subequal, hexagonal, and alternate, except just in front of the glabella. The fourth, fifth, and occasionally sixth rows are of successively smaller pits, and show a decided radial arrangement nearly all the way round. These features are clearly developed in the smallest specimens which I have seen, one of which measures across the fringe only 7 mm.

In specimens from Pwllheli the inferior plate has the concentric ridge between the third and fourth rows nearly as strong as the girder between the second and third, and the differentiation of the plate into an outer and inner band is obscure. The pits in the four outer rows are radially arranged, but those in the two outermost rows are smaller and tend to lie in grooves in front. Towards the genal angles there are some extra pits intercalated in the first row, more or less destroying the radial lines, and the pits in the third row become larger. A fifth row is inserted laterally alongside the cheeks.

On the upper plate there are four rows of pits of equal size and at equal distances apart, arranged in weak radial grooves, and a fifth row is inserted laterally. The correspondence, therefore, in this form between the upper and lower plate is complete, and the regularity of the radial arrangement in weak grooves is a marked feature, distinguishing it from the Onny River specimens.

In the specimens of *T. concentricus* from Dinas Mowddy, which Salter[1] termed var. *Caractaci*, and McCoy[2] labelled *T. gibbifrons*, the lower plate has the same general characters as those from Pwllheli, but in the upper plate a few smaller pits intercalated in the first row interrupt the regularity of the radial arrangement of the four main concentric rows.

The specimens of *T. concentricus* from Allt y Anker and Rhiwargor have a strong girder inside the two outermost rows on the lower plate, while in the upper plate there are regular radial grooves in which lie the pits of the four concentric rows, and all the pits are of equal size, except in a few cases in which those of the first row are rather smaller.

T. favus,[3] which is marked by the unusual outline of the fringe, has the pits in the outermost row of the lower plate more numerous, rather smaller, and more closely placed than those in the second and third rows. All these three rows have their pits increasing in size on each side of the middle line, especially near the anterior lateral angles

[1] Salter, dec. vii, pl. vii, p. 6.
[2] McCoy, Brit. Pal. Foss., p. 145.
[3] Salter, Mem. Geol. Surv., vol. ii, pt. i, p. 350, pl. ix, fig. 3; vol. iii, p. 517, pl. xiii, fig. 9; dec. vii, pl. vii, p. 6.

of the fringe, but they decrease again in size towards the genal angles. Thus the largest pits are found near the frontal angles. A fourth row of smaller pits follows inside the third row, and two short rows are inserted at the anterior angles of the cheeks. The pits in the rows alternate at the sides, but are more or less radial in front.

On the upper plate there is a similar development of pits, and in the front part of the fringe the radial arrangement of the pits of the four concentric rows and their gradual increase in size to the lateral angles are well seen, but further back the radial arrangement is lost and they alternate. A fifth, sixth, and occasionally a seventh row, all of smaller pits, are developed inside at the angles, as on the lower plate, and more small ones at the genal angles, where the regularity of position is lost.

The Tyrone examples of *Trinucleus*, which have been referred to varieties of *T. concentricus* by various authors since Portlock divided them up into several species, show special features of interest and some peculiar characters. In only a few cases is the lower plate of the fringe known, and the association of upper and lower plates is often uncertain.

The specimen (now in Jermyn Street Museum) figured by Portlock[1] as intermediate between his *T. elongatus* and his *T. Caractaci* shows the cast of the lower lamella of the fringe in position with the head-shield. There is a single row of pits on the outer band outside the girder; a second row immediately inside the girder has its pits as large and in the same radii as those of the first row, and continues regularly back to the base of the genal spines. A third row is only developed from the front of the cheeks backwards, and the pits alternate. A fourth row of small pits is present at the sides only. But in the slightly re-entrant angle between the projecting anterior end of the glabella and the cheeks there are 3–4 partly fused minute pits in 5–6 short radial lines, while at the genal expansions there are, as usual, large irregularly distributed pits.

The specimen figured by B. Smith[2] from Tyrone as *T. Portlocki* (which according to Salter[3] is a variety of *T. concentricus*, including Portlock's *T. Caractaci* and *T. latus*) is the cast of a lower plate and has identical characters with the above.

The upper plate of *T. elongatus* represented by Portlock (op. cit., pl. iB, fig. 7) shows strong radial sulci in front, holding three pits in a line, but the sulci and regularity of arrangement are lost at the sides, where the pits of the three concentric rows are alternate and are reinforced by a fourth inner row, while at the genal expansions six or seven short concentric rows of smaller pits are inserted.

In *T. Portlocki*, as represented by numerous specimens from Tyrone, the lower plate has only one row outside the girder, as in *T. elongatus*, and as far as its other characters are known seems to be indistinguishable from it. The upper plate of the fringe which was preserved in the type, and from which its characters were summarized by Salter "punctis ad frontem subradiatis et in ordines 3 contractis", shows four concentric rows of pits in well-marked regular radial lines, with only three rows

[1] Portlock, Geol. Rep. Londond., pl. iB, fig. 6.
[2] Fearnsides, Elles, & Smith, op. cit., pl. viii, fig. 1.
[3] Salter, dec. vii, pl. vii, p. 6.

just in front of the glabella owing to its encroachment on the fringe. The pits, which are of subequal size (except in the third in front, which is there smaller), are sunk in somewhat indefinite radial sulci in front; all the pits become larger laterally and posteriorly, with a loss of the regular radial arrangement by the intercalation of pits in the first row, and are mostly alternate. At the genal expansions many much smaller pits are developed inside the main rows. Thus the fringe seems identical with that of *T. elongatus*.

Smith's var. *arcuatus* (op. cit., p. 122, pl. viii, figs. 5, 6) is imperfectly known and somewhat unsatisfactorily defined, but it has no close relation with *T. fimbriatus* of Murchison, as Portlock thought, if it is the form mentioned by him as intermediate between his *T. latus* and this species. In the so-called var. *expansus* (Smith MS.) the lower surface of the fringe is unknown, and on the upper plate there are (as in var. *arcuatus*) only 2–3 pits in the radial grooves in front, but the radial arrangement and grooves are lost at the sides; an additional row of small pits is here inserted between the first and second, and in all three rows the pits finally alternate, but the pits do not increase so markedly in size when the rows are traced posteriorly as they do in *T. Portlocki*, and the pits which are developed on the genal expansions are smaller, closer together, and more numerous.

The characterization of the fringe of these Tyrone forms is not marked, and the separation of the varieties from one another by this means is not obvious. It appears probable that they are not fixed or well established varieties, but merely individual variations of one extremely unstable species, as will be further discussed in the sequel.

Passing to *T. Nicholsoni*,[1] which has been shown elsewhere to be allied to *T. concentricus*, we note that the outer band of the inferior plate of the fringe bears two rows of equal radially arranged pits, while the inner concave band behind the well-marked girder bears two rows of pits in front, increasing to three rows at the sides. All these inner rows have their pits arranged in the same regular radial fashion and on the same radii as those on the outer band, and are all of equal or subequal size (Pl. XIX, Figs. 4, 4*a*).

The upper plate has similarly four rows of pits arranged in depressed regular radial lines, but not in distinct sulci, with a fifth inner row inserted at the base of the cheek posteriorly. These pits correspond with those on the lower lamella, and their arrangement agrees precisely.

T. seticornis.—The British forms attributed to this species show several variations of more or less importance in the character of the fringe both on the upper and lower plates.

In specimens from Rhiwlas the lower plate shows two regular rows of equal-sized pits, not lying in sulci but radially arranged, on the outer band, while on the steeply inclined concave inner band there are 3–4 rows of smaller pits in distinct radial sulci corresponding in number, and these sulci have corresponding ones on the upper plate, but they are there less pronounced and they hold five pits in front of the glabella and 6–7 at the sides.

In specimens from Applethwaite (Coniston Limestone) the two

[1] Reed, Geol. Mag., Dec. V, Vol. VII, p. 212, Pl. XVI, 1910.

outer rows of pits on the lower plate, which are separate and radially arranged at the sides, approach one another in front and fuse into one row, so that the girder has here only a single row of pits outside it. The pits on the inner concave band are arranged in three or more rows and in radial lines equal in number to the pits on the outer band, but do not lie in sulci.

In specimens from Norber Brow the two outer rows on the outer band fuse into one as in the Applethwaite form, but the pits of the third row (i.e. the first one inside the girder) become larger in front, and the radial lines of 3–4 pits slope inwards to the median axial line on each side.

In a specimen in the Jermyn Street Museum from Cynwyd, Merioneth, there is a similar reduction to a single row on the outer band in front, but on the concave inner band the 3–5 rows of small pits lie in sulci in front and half round the sides, while the sulci become obsolete further back. Just inside the girder at the sides of the cheeks at the base of these radial sulci there is intercalated a single detached row of larger pits in the same radii as those on the outer band.

Examples from Pusgill Beck show two regular continuous rows of pits radially arranged, but not in sulci, on the outer band, and in the same radii on the inner band lie 3–4 rows of smaller pits in shallow sulci extending round nearly to the base of the cheeks. On the upper plate the reverse is found, the inner rows having the pits lying isolated and not in grooves, while there are radial grooves in the outer part of the fringe each holding three pits, the outermost pit being additional, smaller, and not represented on the lower plate.

In the numerous specimens from the Redhill Stage of the Haverfordwest area the two rows on the outer band of the lower plate have the pits radially arranged and distinct, and not in grooves; the pits of the outer row are apt to be rather larger than those of the second row. On the inner concave band there are radial sulci agreeing in number with the pits on the outer band and holding 2–3 small pits. On the upper plate there are two outer rows of pits lying in short radial sulci, and inside them on the roll are rows of small pits radially arranged and corresponding to those on the lower plate but not placed in sulci. In some cases these inner radial lines of small pits are more numerous than the pits in the outer grooves.

The specimens from the Sholeshook Limestone agree with those from the Redhill Stage in the characters of the lower plate, except that the pits of the two rows on the outer band are equal in size, and on the inner band the radial sulci (which usually hold 3–4 pits) die out near the genal angles. In some individuals, however, we notice that the pits on the outer band lie in radial grooves and are more or less fused. An intermediate condition is found in specimens from the Slade Beds, for in them it is only the pits in the median front portion of the outer band which tend to lie in grooves, those at the sides being isolated (Pl. XIX, Figs. 5, 5*a*).

The specimens from Tyrone attributed to *T. seticornis* by B. Smith[1]

[1] Fearnsides, Elles, & Smith, op. cit., p. 122, pl. viii, figs. 7, 8.

are of interest, for the lower plate of the fringe shows a narrow horizontal outer band bearing only one row of pits in front, which laterally by transverse division splits into two rows in regular radial lines. A strong girder separates off the concave inner band, which bears a corresponding number of regular radial sulci holding 2–3 pits, the sulci becoming weaker or obsolete near the base of the cheeks. The pits in these sulci are rather larger and fewer than we usually find in *T. seticornis*, and this is particularly the case with the corresponding pits on the upper plate, which do not lie in distinct sulci. The two outer rows on the upper plate are distinct at the sides, but fuse into one in front; the radial arrangement of the lower plate is preserved. This form by the reduction of the rows to one on the outer band is like *T. Bucklandi* from Girvan, and indeed is indistinguishable from young examples of it, but a similar type of structure in the fringe has been mentioned above in specimens of *T. seticornis* from Applethwaite, Norber Brow, and Cynwyd.

Examples of *T. seticornis* from Portraine possess a lower plate with two rows of large radial pits on the outer band, and behind the strong girder there is first a separate row of isolated pits and then three inner rows of smaller pits in radial sulci, both agreeing in number with the outer rows. The upper plate has no definite roll, but there are two marginal rows sunk in grooves with 4–5 inner rows of slightly smaller pits, all arranged in regular radial lines.

T. Bucklandi from the Sholeshook Limestone, which is doubtfully separable as a species from the *T. seticornis* of this horizon, has the 5–6 rows of radially arranged small pits on the inner band of the lower plate more or less fused and lying in radial sulci which are more numerous than the pits of the two rows on the outer band. The upper plate has the corresponding inner rows of small pits in the roll lying separate and not in radial grooves.

The better-known *T. Bucklandi* from Girvan [1] has only a single row of pits in front on the inferior plate outside the girder, but on each side this row splits into two rows of radially arranged pits, as Nicholson and Etheridge described.[2] These pits on the upper plate lie in sulci and are more or less fused, but the sulci die out on the posterior portions of the fringe. The inner band on the lower plate bears radial lines of small pits sunk in sulci, with a single row of larger pits alternating with the radii intercalated at the base of the sulci just inside the girder. A similar row is sometimes present on the upper plate on which the radial rows on the roll do not lie in sulci.

In the largest examples from Girvan attributed to this species there is an abnormal development of pits, at any rate on the upper plate; for there are three rows of pits lying in the radial sulci near the margin instead of two, and between them and the base of the roll there are about three irregular rows of large, mostly alternating pits; the roll carries two or three concentric rows of more or less sunken radially arranged pits of equal size, and the radii are more numerous than the pits in the marginal rows.

[1] Reed, Mon. Girvan Trilob. (Palæont. Soc.), pt. i, p. 10, pl. i, figs. 10–14.

[2] Nicholson & Etheridge, jun., Mon. Silur. Foss. Girvan, fasc. ii, p. 193, pl. xiii, fig. 19.

In all these specimens of *T. seticornis* and *T. Bucklandi* the division of the fringe into an outer and inner band (which has been shown to be well marked on the lower plate by the girder in nearly every species, but is not similarly defined on the upper plate) is indicated by the marginal portion of the upper plate being horizontal and the inner portion more or less convex and steeply inclined so as to form a kind of roll under the front of the glabella and the cheeks dying out at the genal expansions. This roll, of course, corresponds to the concave inner band of the lower plate. Barrande [1] described and figured this feature in the Bohemian examples of *T. Bucklandi*, but in immature individuals he remarked that the differentiation was not developed.[2] Salter [3] stated that "the fringe is always steeply bent down and follows the declivity of the cheek without any change of direction, except in some specimens a gentle convexity".

The above remarks on the variation in the characters of the fringe in British examples of *T. seticornis* are not intended to suggest a classification based on these features alone. Any scheme of grouping together the various forms of this species must be based, if possible, on an aggregate of characters of all parts of the trilobite, and not on the fringe alone, although frequently we have to depend only on the head-shield. When the peculiarities of the glabella and cheeks have been discussed we shall be in a better position to make such an attempt. But the foregoing somewhat detailed account of differences in the fringe has been given to illustrate the amount of agreement or want of similarity which may exist between the upper and lower surfaces of the fringe of the same form. The general conclusion from these observations points to a fairly general and complete correspondence in the number of pits and rows on the two plates, but to frequent dissimilarity in the matter of radial sulci.

With regard to the connexion established by means of corresponding pits between the upper and lower surfaces in *T. seticornis*, it appears to be the case that there is generally no uninterrupted communication by means of the small pits on the roll and on the inner band, these pits being usually imperforate and merely indentations in the surface and substance of the plates; but the marginal pits and those at the genal expansions are perforated or connected by short tubes, as in *T. concentricus* from the Onny River.

Imperfectly known species.—There are several other British species which have been described and whose names have found their way into geological literature, but with regard to our knowledge of their fringe much is to be desired. In most cases figures have been given of the head-shield exhibiting only the characters of the upper surface of the fringe. Such are the following forms:—

(1) The species of *Trinucleus* from the Whitehouse Beds of Girvan described as *Trinucleus* sp. *b* by me in 1903 [4] is now better known, and with regard to the fringe it shows on the upper surface two rows of radially arranged large pits which in front tend to sink into short

[1] Barrande, Syst. Silur. Bohême, vol. i, p. 621, pl. xxix, figs. 10–17.
[2] Ibid., pl. xxx, figs. 14–16.
[3] Salter, dec. vii, pl. vii, p. 7.
[4] Reed, Mon. Girvan Trilob., pt. i, p. 14, pl. ii, figs. 8, 8*a*; suppl., p. 160.

radial sulci; towards the genal angles the rows diverge somewhat and the pits are quite separate, and a short irregular row of a few pits is inserted at the posterior outer angles of the cheeks. The lower plate of the fringe of this species is not known.

(2) Another imperfectly known species as regards its fringe is *T. Sedgwicki*, Salter,[1] in which the upper surface of the fringe bears two outer rows of large pits sunk in radial sulci, and several inner rows of smaller pits "not strictly regular and more in number than the outer rows". As regards these features it suggests relations with *T. subradiatus*.

(3) The rare species *T. thersites*, Salter,[2] only found by him at Tramore, has a fringe with the upper surface possessing two regular concentric rows of an equal number of pits of equal size radially arranged, with an inner third row of fewer pits which are larger and widely spaced in front of and at the sides of the glabella, and are not here radially arranged, but posteriorly are more closely placed and no larger than the outer rows and divide into two and finally into three rows with their pits in radial lines near the genal angles and tending to lie here in shallow grooves and in the same radii as the outer row of pits. The lower surface shows a well-marked girder inside the two outer rows which correspond in development to those on the upper surface; there is a similar inner third row apparently continuous right round, and like the one on the upper surface dividing into two and then three rows posteriorly. This species has apparently never been figured.

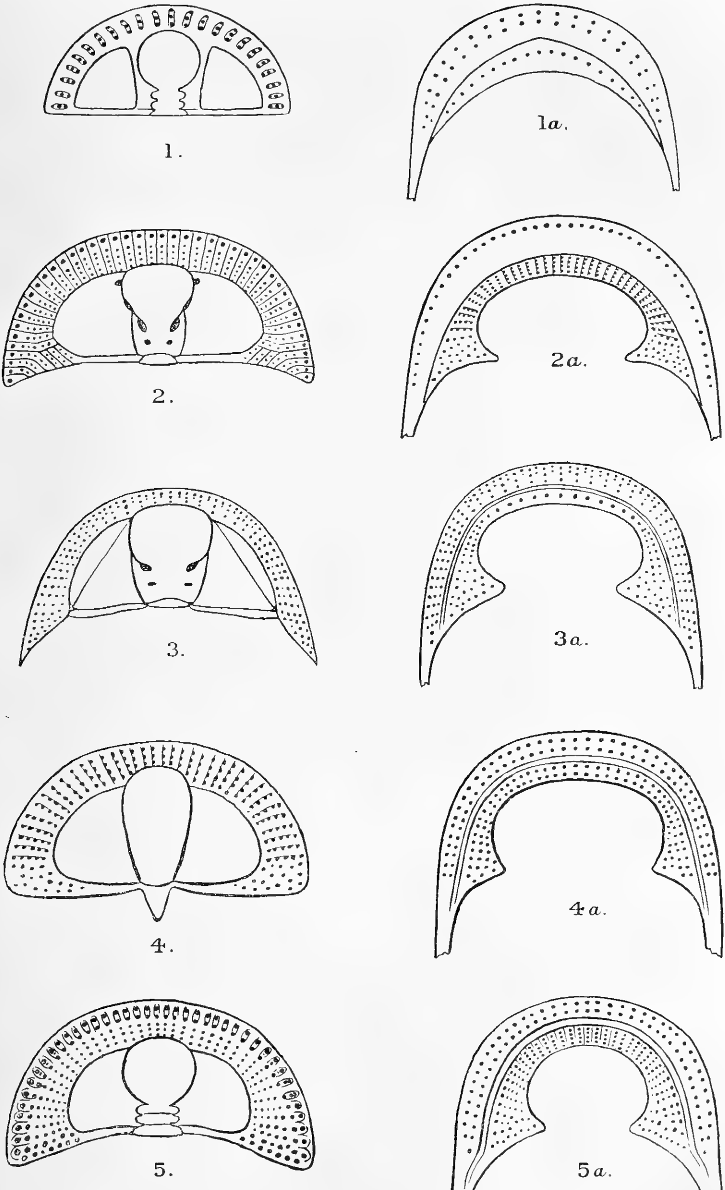
(4) *T. radiatus*, Murchison,[3] was founded on some fragments of head-shields showing a peculiar type of fringe described as follows:— "Marginal pores arranged on the front of the head in one or two rows; on the sides in long radiating lines. Buckler square, lateral spikes short." The examples of this species in the Jermyn Street Museum from Builth have in no case the complete fringe preserved, and only portions of the impression of the lower plate are present.

(5) *T. Ramsayi*, Hicks.[4] It has recently been pointed out by me[5] that this Trilobite is probably referable to the genus *Dionide*, and must certainly be removed from *Trinucleus*.

EXPLANATION OF PLATE XIX.

FIG. 1. *Trinucleus hibernicus*, Reed. Diagram of upper surface of fringe.
,, 1*a*. Ditto. Ditto of lower surface.
,, 2. *T. fimbriatus*, Murchison. Diagram of upper surface of fringe.
,, 2*a*. Ditto. Ditto of lower surface.
,, 3. *T. Murchisoni*, Salter. Diagram of upper surface of fringe.
,, 3*a*. Ditto. Ditto of lower surface.
,, 4. *T. Nicholsoni*, Reed. Diagram of upper surface of fringe.
,, 4*a*. Ditto. Ditto of lower surface.
,, 5. *T. seticornis* (Hisinger). Diagram of upper surface of fringe (Sholeshook form).
,, 5*a*. Ditto. Ditto of lower surface.

[1] Salter, Mem. Geol. Surv., vol. iii, p. 516, pl. xii, fig. 9.
[2] Salter, Dec. Geol. Surv., vol. vii, pl. vii, p. 7.
[3] Murchison, Silur. Syst., p. 660, pl. xxiii, figs. 3*a*, 3*b*.
[4] Hicks, Quart. Journ. Geol. Soc., xxxi, p. 183, pl. x, figs. 1, 2, 1875.
[5] Geol. Mag., Dec. V, Vol. IX, p. 202, 1912.



T. A. Brock del.

Structure of the 'fringe' around the head-shield of five species of *Trinucleus*.

II.—On *Archarenicola Rhætica*, sp. nov.

By A. R. Horwood (Leicester Museum).

(PLATE XXI.)

General Notes on the Horizon of Specimens A and B.

In the latter part of 1910 I was agreeably surprised upon the examination of some material from the Rhætic Black Shales at Glen Parva, Leicestershire, to detect a specimen which at the moment I recognized as new (specimen A).

Reference to this discovery, and to that of a second example in the Museum collections (specimen B), has already been made in brief[1] in the hope that, if other material of the kind existed, I might be apprised of it. So far, however, no further specimens have been obtained.

Specimen A, upon which I found the type, was not found in situ, but the burrows which undoubtedly belong to it are commonly found at 1 to 2 feet above the bone-bed, here the base of the Rhætics, overlying Tea-green Marl.

Specimen B was found by me amongst some old material in this Museum, which I have every reason to believe came from the now covered-up exposure of Rhætic beds at Spinney Hills, reported by the late Mr. W. J. Harrison, F.G.S., a former curator.[2] This specimen came from the bed numbered 5 in the section given, "sandstone 1 inch." On the other side are broken shells of *Avicula contorta*.

Review of Grouping of Fossil Polychætes.

Amongst Fossil Annelids so far only traces of Marine Polychætes have been detected. These have been subdivided into two groups—(*a*) *Tubicola* (Sedentaria), in which the parapodia are short and not used for swimming and in which the animal lives in a tube; (*b*) *Errantia* (Nereidæ), in which the animal is free-swimming and has a well-marked head, well-developed parapodia, with setæ used for locomotion. Some forms included here possessed powerful jaws.

There are really no authentic Palæozoic impressions, since those included in *Nereites*, *Nemertites*, *Myrianites*, *Nemapodia*, *Crossopodia*, *Phyllodocites*, *Naites*, etc., have been regarded as due to movements of Crustacea, Annelids, Gasteropods, and are not impressions of the cuticle at all.[3] This being so, the impressions here described must be regarded as belonging to a new order, and they belong to a different group, or Arenicolidæ.

The burrows included the genera *Scolithus*, *Arenicola*, *Histioderma*, *Planolites*, *Diplocraterion*, *Spirocolex*, *Scolecoderma*, some of which were described or grouped by Nicholson.[4] He considered, as did Nathorst, some of the trails or tracks were perhaps formed by Annelids, Crustaceans, or Molluscs.

[1] Rep. Brit. Assoc. Portsmouth, Trans. Sections, 1911.

[2] "On the occurrence of Rhætic Beds in Leicestershire": Q.J.G.S., 1876, p. 212.

[3] A. G. Nathorst, "On the Tracks of some Invertebrate Animals and their Palæontological Significance": K. Svensk. Vetensk. Akad. Handl., Bd. xviii, xxi, 1881–6.

[4] H. A. Nicholson, "Contributions to the Study of the Errant Annelids of the Older Palæozoic Rocks": Proc. Roy. Soc., 1873, p. 288.

As to the first group the burrows, such as *Bilobites*, *Rusichnites*, *Arthrichnites*, *Protichnites*, *Climactichnites*, *Scolithus*, have been regarded also by Dawson[1] as due to the movements of various Invertebrates and not as Annelid burrows especially. *Sabellarites* he described as a new sand-tube, and *Buthrotrephis* as a true Fucoid from the Silurian.

The similarity between such impressions and those of the markings made by Molluscs and Crustacea had been pointed out by Professor McKenny Hughes,[2] so that a great clearance has been made of some of the old lumber that cumbered the ground in the domain of fossil Annelids.

Though this Annelid with its cuticular investment constitutes a new group, I think it unnecessary to make a third for its reception.

Notes on Specimen A. (Pl. XXI, Fig. 2.)

Size. Extreme length, 6 cm. Greatest width (upper end), 18 mm.; at centre, 16 mm.

Measurements between annuli. Distance between annuli, 1–2 mm. (5 to a centimetre).

The distance between the annuli varies irregularly; there are some shorter furrows between longer ones, especially in the anterior half, which is the underside of the raised or relief portion.

In *shape* it is a vermiform impression, slightly curved from below to the left. The impression being flattened, it is difficult to estimate the real diameter or girth of the animal originally. Compressed it forms a thick impression 3 mm.

The posterior portion has a stained outline, 5 mm. thick, on the right side, due to the exudation of animal matter or juices from the soft body preserved in the mud in some combination which is probably bituminous. A portion of the left posterior margin also shows the same character. Wherever the impression is preserved in the Black Shale the same greenish-brown external outline may be seen.

Segmentation. The term annuli has already been given to the transverse ridges that regularly cross the body. Whether it is possible to distinguish the definite arrangement of these annuli into segments, each consisting of so many annuli, cannot be determined owing to the manner of preservation. In *Arenicola*, of which I regard this fossil as a prototype, there are five annuli in each segment, one being larger than the rest and bearing the parapodia. As already noticed there is in specimen A a certain differentiation into two sizes, a large and a small annulus alternating. And to all appearance the appendages, chætigerous parapodia, are attached to the base of the larger annulus. But on this point it is impossible to speak with absolute certainty. In *Arenicola* there are three segments in front of the one bearing parapodia and one behind, and it is possible that the intercalation of three achætous segments is a new feature gained during the evolutionary progress of the genus, or that the apparent arrangement of alternate large and small segments is a variation of it.

Appendages. The body of *Arenicola* may be divided into three regions—an anterior with parapodia, without gills, a middle portion bearing both, and a posterior achætous portion.

The portion of the body to which specimen A may be said to correspond is the anterior non-branchiate portion. Though at first it appeared to be achætous, this portion does undoubtedly exhibit appendages which correspond to the notopodial setæ of *Arenicola*. If the capillary appendages on either side seen at intervals are notopodial setæ, the neuropodia must be invisible and beneath

[1] "On Burrows and Tracks of Invertebrate Animals in Palæozoic Rocks and other Markings": Q.J.G.S., 1890, p. 595.

[2] "On some Tracks of Terrestrial and Freshwater Animals": Q.J.G.S., 1884, p. 178.

the impression. There is, in fact, no sign of crotchets opposite the straight chætæ. These last are short, barely 5–6 mm. long, and are borne in fascicles so closely associated that they cannot be counted. They are not visible in every part, but are indicated by folds in the matrix, which may be taken to show their position. Within the broken portion of the body-surface in the posterior part are some detached chætæ of a similar nature. As a rule they bear a strong resemblance to the chætæ of *Arenicola marina*. It is not possible to distinguish any spathulate chætæ similar to those in *Arenicola*. As a whole they bear a resemblance to the parapodia of *Nereis*, but are not present on each annulus as in *Nereis*, and the annuli themselves do not show any trilobed divisions as in that genus. The appendages in fact most nearly approach those of *Arenicola*.

Surface. The surface of this fossil for 4·5 cm. of its length is the original cuticle of thick cells which now preserve only the form and arrangement of the external somites and annuli and the epidermal surface characteristics. The upper portion, 1·5 cm., is a cast of the inner surface of the cuticle, and possesses no surface features. As the anterior epidermis of this specimen is wanting, it is impossible to say whether it was like the lower part or not.

In *Arenicola* the anterior and middle part of the cuticle is divided up into well-marked contiguous polygonal areas which give it a wrinkled appearance. In the tail the cuticle is covered with prominent papillæ similar to the anterior arrangements in structure, and doubtless derived from similar definite polygons, originally, becoming rounded or sharply defined with age.

In the specimen A the cuticle is covered with raised papillæ which do not occur on the matrix itself, and are impressions of the papillæ found in *Arenicola* on the tail part. Whether this type had papillæ alone or on the anterior part remains to be investigated. But this worm must have presented in this and other characters already noted a very strong resemblance to the modern lug-worm. The anterior third representing the inner surface retains traces in part of the inner tissue, belonging perhaps to the longitudinal muscles, but there is no structure preserved, as everything, except perhaps some chitinous chætæ, is replaced by the black shale matrix.

An exception may be made to the last statement perhaps in the case of the brown layer or ring surrounding the impression itself posteriorly. It is almost certain that this has been produced by a similar substance to the green or yellow pigment which is exuded in recent lugworms by the skin. It is thought by Ashworth to be a lipochrome. Another brown or black pigment insoluble in alcohol is like melanin in this respect, and may be derived from the yellow lipochrome. Indeed, Farroll showed that melanin could be due to chemical change in lipochrome under the influence of an acid. The further homology thus afforded by the probable identity between the brown stain and the pigment exuded by *Arenicola* makes the resemblance irresistible.

Head portion. In endeavouring to uncover part of the impression I found on the left side, in the posterior portion, an impression and counterpart of a terminal part of a similar annelid. This exhibits all the characters of the figured portion, and may be taken to be the head or anterior portion. No details as to the proboscis, peristomium, or other parts can be made out, as it is badly preserved, but there is a cast of what may be regarded as a protruding prostomium with a bifid apex, the lines of the straight stem or base of the prostomium being deeply impressed as two parallel lines, whilst the apex is in bas-relief; and as the other portion in alto-relievo does not show this, it is not possible to be absolutely certain as to the real outline of the structure. It is not exactly like that of *Arenicola*, but bears a considerable resemblance to it. The buccal papillæ of the proboscis, which is not clearly present, are not to be seen, so that it was not protruded. Had this worm been a *Nereis*, which the head portion might have indicated, it would have exhibited palps and tentacles and peristomial cirri, which *Arenicola* does not possess, and as there is no sign of these the homology in this instance again may be taken to be correct. It is fortunate indeed that this terminal portion came to hand, since it settles a point as to which otherwise there might have been difference of opinion.

Burrows. The shales in which this fossil (specimen A) occurs are commonly traversed by burrows which may, and in fact almost certainly must, have been the burrows of this Annelid. They are small in comparison, but have doubtless shrunk and become compressed since they were made. Most are horizontal, and if belonging to a worm of the *Arenicola* type, they belong to the horizontal part of the U-shaped burrow such as it makes in marine sands at the present day. They are irregular and not of great length, though the fragmentary material found can hardly be said to give an adequate idea of their length or true nature. Whether they were U-shaped or not is not clear.

Resemblance to a Myriapod, and difference. There is a superficial homœomorphy between this fossil and some fossil Myriapods. But there is no telson, no spiracles, no spines, the appendages are different (as are the annulation and segmentation). There are no ocelli, and the walking-feet of such fossils as *Acantherpestes* and *Euphoberia* are quite different. *Archarenicola* bears, indeed, on the whole a distinct Annelid character, whilst the fossils called Myriapods are quite distinct.[1]

The only resemblance lies in the fact that there is an outline which is regarded as due to the extrusion of the viscera, comparable with the brown zone that we suggest is due to staining by juices exuded by the Arenicola type of Polychæte.

Affinities. Having regard to the character of the head portion of specimen A and the parapodia, there can be no hesitation in placing this fossil in the group Phanerocephala, in which the prostomium is distinct, and the segmentation is of the same type.

As regards the sub-order to which it may be referred, there is no doubt that the absence of tentacles, palps, and peristomial cirri, and the simple nature of the parapodia which project, place it in the Scoleciformia, amongst which we find the family Arenicolidæ. The capillary setæ, absence of tentacles, palps, etc., place it in this last family. Whether it should belong to the caudate or ecaudate section is not demonstrable from the material so far to hand, but I should expect from its general characters in other respects that it belongs to the second.

Specimen B. (Pl. XXI, Fig. 1.)

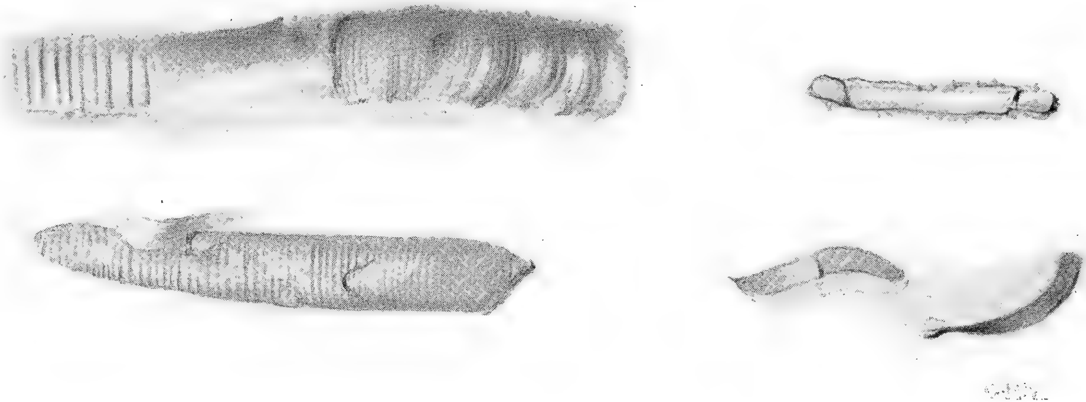
Size. Extreme length, 8·25 cm.; greatest width, 1 cm.

Measurements between annuli. The distance between the annuli is 2 mm. The annuli themselves measure as much, and the furrows between are deeply marked. This specimen is preserved in an indurated sandstone, and the impression is better marked anteriorly as regards annulation, having a less flattened appearance. At the posterior end the annuli are not so far apart. Anteriorly there are five to a centimetre, and each annulus is equidistant, except in one case, where it is 3 mm. distant from the next. For a great part the impression is covered by the matrix, which it is difficult to remove with advantage. Where it is uncovered elsewhere a black slickenside-like covering obscures the segmentation.

Surface. The anterior portion is an inside cast of the surface, except along the margin, and bears no papillæ. The posterior portion is covered by a black slimy covering, which may originally have been slimy bitumen, containing

[1] "Fossil Myriopods from the Middle Coal-measures of Sparth Bottoms, Rochdale, Lancashire": Geol. Mag., 1912, p. 74.

2 1



3 4

Archarenicola rhætica, A. R. Horwood, sp. nov. Lower Rhætic : Glen Parva, Leicestershire.

juices exuded by the worm, in this case black. Underneath this, about the centre, are indications of the polygonal areas found anteriorly in *Arenicola*. A few papillæ are present here. Otherwise this specimen is very similar in surface characters to the type, specimen A.

Appendages. There are very few indications of appendages in this specimen, and they are similar in character to those in specimen A, but are only distinct on one side, the left, where they are distant. They are notopodial setæ without a doubt, but though only seen on one side there is no trace of neuropodial crotchets as in specimen A, and they may both therefore be regarded as viewed from the dorsal aspect.

ARCHARENICOLA, NOV. GEN.

An annulated Polychæte, with an impression of the cuticle bearing annuli of two sizes, possibly forming segments. The cuticular surface is covered in the type by epidermal papillæ, in the co-type by polygonal areas between the somites. The appendages are paired, on alternate annuli, consisting of capillary notopodial setæ. The head bears no appendages, but indications of a frilled prostomium. The impression is surrounded by a zone caused by exudations of the juices, as in the present-day *Arenicola*.

ARCHARENICOLA RHÆTICA, SP. NOV. (GENOTYPE).

Characters of the genus, based on specimen A (type) and specimen B (co-type).

Specimen A (Pl. XXI, Fig. 1). Horizon: Lower Rhætic—Black Shales. Locality: Glen Parva, Leicestershire.

Specimen B (Pl. XXI, Fig. 2). Horizon: Lower Rhætic—Black Shales. Locality: ? Spinney Hills, Leicestershire.

Both specimens are deposited in the palæontological collections of Leicester Museum, where they form the third type species of local origin.

I am greatly indebted to the discoverer of the type, Mr. A. J. S. Cannon, for the opportunity of seeing this and other Rhætic fossils of interest, and for much help in other ways. I have to thank Miss G. M. Woodward also for the care which she has taken in preparing the plate.

EXPLANATION OF PLATE XXI.

FIG. 1. *Archarenicola rhætica*, sp. nov. Specimen A. Lower Rhætic: Glen Parva. Nat. size.

,, 2. *Archarenicola rhætica*, sp. nov. Specimen B. Lower Rhætic: ? Spinney Hill, Leicestershire. Nat. size.

,, 3, 4. Burrows of *Archarenicola rhætica*, in Black Shale, Glen Parva. Nat. size.

III.—NOTES ON LATERITE IN WESTERN AUSTRALIA.

By EDWARD S. SIMPSON, B.E., F.C.S., Geological Survey of Western Australia.

(Communicated by permission of the Government Geologist of Western Australia.)

THE following notes on the laterites of Western Australia are the outcome of a careful study of the series of articles contributed to the GEOLOGICAL MAGAZINE during the latter part of 1911 by Dr. L. Leigh Fermor, entitled "What is Laterite?" These deal with the subject from the point of view of one having an intimate knowledge of Indian laterite, but not a first-hand acquaintance with those of other parts of the world. The present writer, during the last fifteen years, has devoted much time to the study of the laterite of extra-tropical Western Australia, both in the field and in the laboratory, and is therefore in a position to supplement some of the work of Dr. Fermor, whilst inclined to differ from him in some of his deductions.

Broadly speaking, the laterite of Western Australia may be divided into two classes—

(1) Primary Laterite (true laterite, high-level laterite), formed in situ out of soluble material derived from the weathering rock immediately underlying it.

(2) Secondary Laterite (lateritite, low-level laterite), composed largely of the mechanically transported fragments of primary laterite.

The study of the latter being dependent on and of secondary importance to the study of the former, it is the primary laterites which have been most closely examined, and will be dealt with almost exclusively in this article.

Primary laterite in Western Australia, and probably elsewhere, is a product of normal processes of weathering, accompanied by abnormal conditions of rainfall and denudation. It is not necessarily confined to tropical areas: immense deposits in this State are extra-tropical. It is simply confined to areas underlaid by suitable rocks, and subject to all three of the favourable conditions just mentioned.

By "suitable rocks" is meant rocks composed largely or wholly of metallic silicates, especially in this State, granite and greenstones of common types, as well as amphibolites, epidiorites, chlorite-schists, and other similar rocks.

By "normal processes of weathering" is meant the attack of the outcrops of such rocks with rain-water carrying atmospheric carbonic acid, the result being the formation of kaolin (crystalline $Al_2O_3 . 2 SiO_2 . 2 H_2O$), halloysite (amorphous $Al_2O_3 . 2 SiO_2 . 2 H_2O$), and quartz or hydrous silica, together with solutions of aluminium hydrate, titanium hydrate, ferrous carbonate, calcium carbonate, magnesium carbonate, manganous carbonate, etc.

The abnormal conditions of rainfall tending to produce laterite are such that the weathering rocks and any products are alternately saturated with water and then again completely desiccated.

A slow rate of denudation is essential.

Primary laterite is a true efflorescence, that is, a deposition on the surface of the ground of substances dissolved by underground water, brought to the surface by capillarity, and there deposited as solid matter owing to aeration and evaporation of the water.[1]

Primary laterite in Western Australia, wherever sunk through, is found to overlie an almost pure pipeclay, and this in turn a crystalline rock. Dr. Fermor holds kaolinization to be a process incompatible with laterite formation.[2] In Western Australia the processes are

[1] *Vide* E. S. Simpson, Bull. 6 of the Geol. Surv. of Western Australia, pp. 39, 78, 79. Published 1902.

[2] Geol. Mag., 1911, p. 459.

contemporaneous and inseparable from one another. Dr. Fermor writes thus:—

"When a rock breaks down into a *clay* hydrated aluminium silicate is to be regarded as the pure end product, all oxides being removed in solution. When a rock is converted into laterite, on the other hand, the reverse holds; aluminium and other silicates are decomposed, and the silica is removed in solution, presumably in the colloidal form, whilst the oxides of iron, aluminium, titanium, and manganese, which were relatively soluble under the clay-forming conditions, are relatively insoluble under laterite-forming conditions. The oxides of calcium, magnesium, sodium, and potassium are apparently soluble under both sets of conditions. I do not propose to advance here any reasons to account for these two diverse modes of alteration of rocks. . . ."

Such an apparently paradoxical postulate seems to require detailed explanation on the part of the author. Surely Dr. Fermor is putting the cart before the horse when he speaks of the concentrated accumulation of lateritic material as due to the leaching away of the non-lateritic products of weathering. The formation of an ordinary efflorescence of salt on the surface of salty ground, or of an efflorescence of gypsum or potassium vanadate on the surface of a brick are phenomena identical with the formation of laterite, but one does not explain them by saying that in the one case the insoluble sand and clay of the soil is dissolved away, leaving an accumulation of insoluble salt, or that in the other case the baked clay of the brick is dissolved away, leaving an accumulation of gypsum or vanadate of potash.

The same remarks indicate the absurdity of referring to a laterite as a true residual, or as a replacement of a rock, i.e. a deposit accumulating in the actual space originally occupied by the solid rock which has yielded the materials which compose the laterite. The primary laterites of Western Australia are deposited, like other efflorescences, outside the surface of the parent rock. Two typical sections are shown in the accompanying figure (p. 402).

Reverting to the question of the distribution of rainfall favourable to the formation of laterite, the extra-tropical portion of Western Australia may be divided into two provinces. One of these lies within 50 to 100 miles of the western coast, where the average annual rainfall is between 20 and 40 inches, distributed between well-defined wet and dry seasons. Typical laterite localities in this area are Mundaring and Greenbushes, the rainfall of which are—

	Mundaring.	Greenbushes.
	Inches.	Inches.
Average annual rainfall . . .	41	$37\frac{1}{2}$
Average November to March .	$2\frac{1}{2}$	3
Average April to October . . .	$38\frac{1}{2}$	$34\frac{1}{2}$

The other province includes the Eastern Goldfields, and has no defined annual wet and dry seasons. The average rainfall is between 7 and 12 inches, one-quarter of which frequently falls in a single day, the usual intervening climatic conditions being intensely arid. As typical examples, Mulline, with an average of 11·2 inches, had a fall of 3·3 inches on one day in 1907; Coolgardie, with an average of 9·4 inches, recorded nearly 4 inches in two closely following days of the same month. These are typical, not abnormal, rainfall conditions.

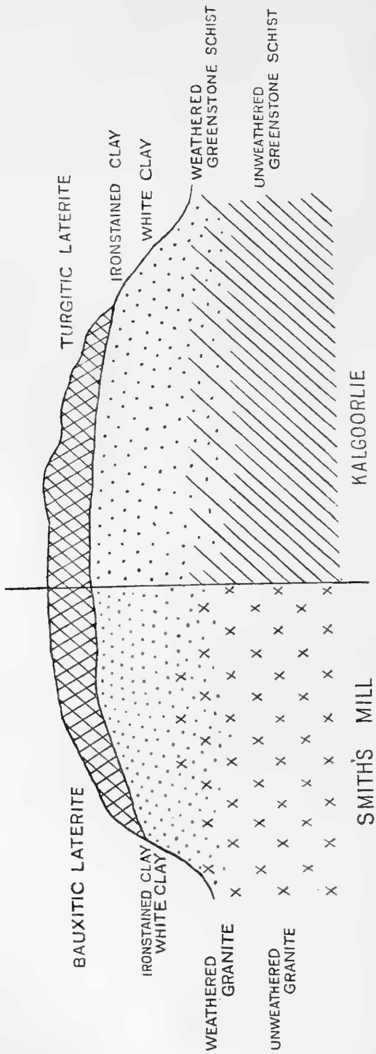


Diagram showing two typical examples of the mode of occurrence of primary laterites in Western Australia.

Although the climatic conditions in these two provinces are so very different, yet the result from the present point of view is identical, viz., short or long periods during which the surface rocks are saturated with meteoric water, alternating with long dry and hot periods, during which they are completely desiccated and the freshly-formed laterite hardened. Such conditions seem to me to favour, if not indeed to be necessary to, the accumulation of laterite.

It would appear that the accumulation of laterite is a very slow process, and cannot take place where erosion is moderately rapid. It tends, therefore, to grow on well-defined peneplains, such as the 1,000 feet Darling Range peneplain, and on the upper very gentle slopes of valleys, where denudation is slow. Bare rock, clay, sand, and secondary laterite carrying sand and clay are found at lower levels. In Western Australia primary laterite is found chiefly between 500 and 1,500 feet above sea-level. Higher altitudes than 1,500 feet are rare within the extra-tropical parts of the State. They are usually devoid of laterite.

The climatic conditions favouring its formation and preservation having been dealt with, the details of its growth need elucidating. It has already been stated that laterite is an efflorescence resulting from normal weathering, the first stage in the process being the conversion of felspars into kaolin and the partial saturation of the sub-surface water with carbonates of iron, manganese, lime, and magnesia, with hydrous silica, titania, and alumina, and finally with alkali salts. With the advent of dry weather this solution begins to evaporate at the surface, and as it evaporates further supplies are brought to the surface by capillary action. A slow but appreciable movement of water from below to the surface goes on till the weathered rock is desiccated. Mere contact of this water with the atmosphere is sufficient to precipitate all the iron and manganese as hydrated peroxides, two important laterite constituents. Evaporation increases the speed of this precipitation, and at the same time leads to the precipitation of all the other substances dissolved in the water. Alumina and silica in the proportions Al_2O_3 to $2SiO_2$ are co-precipitated as colloidal halloysite (lithomarge of Fermor), $Al_2O_3 . 2SiO_2 . 2H_2O$. An excess of silica over this proportion seldom if ever occurs in the water, an excess of alumina is precipitated as hydrate, probably primarily as gibbsite, $Al_2O_3 . 3H_2O$. Titanium is precipitated as metatitanic acid, $TiO_2 . xH_2O$. During the growth of the laterite small amounts of sand and clay become mechanically included.

All the important constituents of laterite are thus accounted for. But in addition to these the evaporating water must have deposited at the same time alkali salts and carbonates and sulphates of lime and magnesia, compounds occurring only in traces in normal primary laterite. The history of the rock is evidently not yet complete. It must be continued over the dry season, during which the typical laterite materials are rendered practically insoluble by consolidation and desiccation, into the succeeding wet season. The soluble alkali, lime, and magnesia salts are then soon taken up by the rain-water and carried off in the streams. The laterite has then reached its final composition.

In structure West Australian laterites are almost always pisolitic, the typical form of an amorphous substance slowly growing by precipitation from solution. The nodules vary in size from that of a pin's head up to about 1 inch in diameter, the average being one-eighth to one-quarter of an inch. The spaces between the nodules are partly filled with similar material to the nodules, partly unfilled. Rarely (e.g. Lone Hill, Kalgoorlie) some of the more ferruginous laterites are devoid of concretionary structure, whilst still containing numerous visible pores.

The composition of some typical laterites is given in the accompanying table :—

COMPOSITION OF WEST AUSTRALIAN PRIMARY LATERITES.

Locality.	Kalgoorlie. (1)	Kalgoorlie. (2)	Kalgoorlie. (3)	Kalgoorlie. (4)	Coolgardie.	Comet Vale.	Boogardie.	Smith's Mill.	Wongan Hills.	Mt. Baker.	Gooseberry Hill.
Fe_2O_3 . .	78·38	75·41	79·41	62·67	80·02	79·01	73·81	10·02	19·08	35·54	39·80
Al_2O_3 . .	9·92	12·29	5·97	12·76	4·32	?	?	46·70	44·66	31·14	36·74
Cr_2O_3 . .	0·01	0·05	0·60	0·08	0·08	5·30	?	?	?	?	0·03
V_2O_5 . .	0·40	0·45	0·65	0·15	0·55	?	?	?	?	?	0·23
MnO_2 . .	0·07	0·41	0·07	0·35	0·13	?	?	?	?	?	0·06
MgO . .	0·35	none	1·56	0·99	trace	?	?	trace	trace	trace	0·15
CaO . .	none	none	none	none	none	?	?	trace	trace	0·16	0·10
TiO_2 . .	2·01	2·55	3·10	6·00	6·06	?	?	0·59	3·10	4·33	1·98
SiO_2, Quartz					0·76						4·44
	2·67	1·77	2·52	2·73		3·14	11·46	17·17	5·96	13·74	
SiO_2, . Combined					1·77						1·97
P_2O_5 . .	trace	trace	trace	trace	trace	0·18	0·05	trace	trace	trace	trace
H_2O . .	6·00	7·05	6·89	14·46	7·06	?	2·86	25·37	27·02	15·40	14·93[1]
	99·81	99·98	100·77	100·19	100·75	?	?	99·95	99·82	100·31	100·43

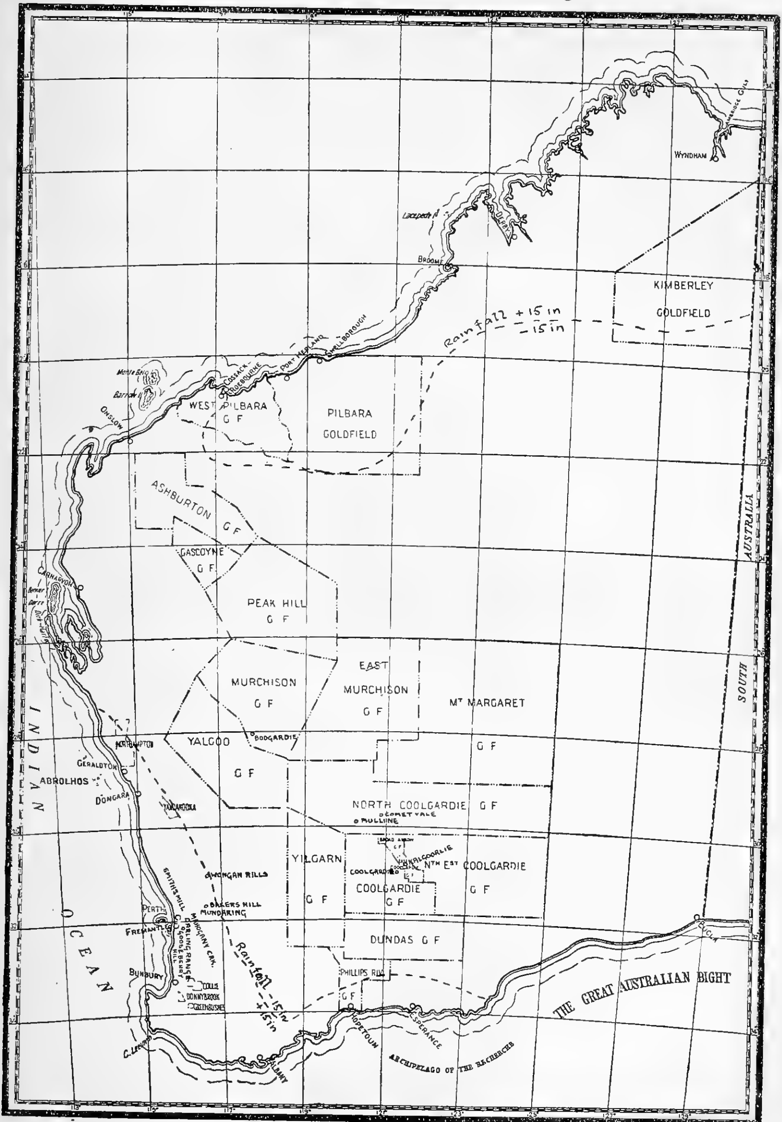
These analyses, though so many of them are incomplete, are an assistance in unravelling the mineral composition of the laterite.

The iron is undoubtedly present as limonite, $2\,Fe_2O_3 . 3\,H_2O$, in many of them, e.g., Kalgoorlie (4), Smith's Mill, and Wongan Hills. Turgite, $2\,Fe_2O_3 . H_2O$, is, however, just as common, particularly in laterites from the interior, such as Kalgoorlie (1), (2), and (3), and Coolgardie. Its presence, suspected from the results of the analyses, was readily confirmed by the decrepitation of the mineral when heated in a closed tube. Gothite, $Fe_2O_3 . H_2O$, and hæmatite are probably present at times. Wherever the laterite overlies greenstone an iron hydrate is the predominant constituent.

Solutions of these laterites in a mixture of sulphuric and hydrofluoric acids, prepared in a neutral atmosphere, are invariably capable of reducing potassium permanganate solution, usually in two distinct stages. For example, the Coolgardie laterite quoted above instantaneously reduced permanganate equal to 0·80 per cent of ferrous oxide, and more slowly (about 3 seconds) a further amount equal to 0·54 per cent ferrous oxide. This consumption of permanganate may be due to the presence of ferrous oxide, vanadium trioxide, or organic matter. No definite interpretation is at present possible, but the writer is inclined to consider that it is in small part due to the presence of a little ilmenite or magnetite, but more largely

[1] 1·20 per cent at 105°.

to the presence of organic compounds of iron. In this connexion it is worth noting that a series of small springs flowing out from beneath



Map of Western Australia, showing localities where laterite has been observed, and referred to in Mr. E. S. Simpson's paper.

the laterite at Mundaring gives rise to a stream which, near the laterite, was found (in 1909) to contain ferrous iron (1·32 grains per gallon) and organic matter, together with insufficient inorganic radicles to satisfy the basic radicles. This water apparently contained organic compounds of iron.

Alumina is present in all the laterites, but most abundant in those overlying granite and other less ferruginous rocks. In the Wongan Hills and Smith's Mill samples it appears to exist as gibbsite, $Al_2O_3 . 3H_2O$, in other cases it is less hydrated, corresponding to bauxite, $Al_2O_3 . 2H_2O$, or diaspore, $Al_2O_3 . H_2O$.

Titanium oxide is always present in appreciable amounts, probably in the form of metatitanic acid, $TiO_2 . xH_2O$, for which no mineralogical name has yet been suggested. Experiments on the Coolgardie laterite showed it was not present, except in traces perhaps, as rutile or ilmenite. The titanium compound was found to be insoluble in warm dilute hydrochloric acid but soluble in fuming sulphuric acid.

Silica is present as (1) quartz, or rarely felspar, mechanically entangled, and (2) in combination in a form decomposed by strong hydrochloric acid, probably halloysite.

Only very small percentages of manganese oxide have been observed.

Chromium oxide has been detected in every case where it was looked for. It varied from a trace to 5·30 per cent. In the latter case it was almost wholly present as chromic hydrate, soluble in strong hydrochloric acid. A small proportion was present as chromite. It is probable that where the percentage of Cr_2O_3 rises above 0·1 per cent the underlying rock is of an ultra-basic type.

Notable amounts of vanadium were detected whenever looked for. The highest proportion noted was 0·65 per cent, V_2O_5 (?), in a turgitic laterite from Kalgoorlie. The form in which this constituent occurs in the rock is not yet determined. This is only one of many unsolved problems connected with this deeply interesting formation.

IV.—On the origin of certain Clay-bands in the Limestone of the Crich Inlier.

By H. C. Sargent, F.G.S.

Introductory.

In the Carboniferous Limestone of the Crich inlier in Derbyshire, there are numerous clay-bands or partings interbedded with the limestone which appear to throw considerable light on the geological history of the area.

These clay-bands vary in thickness from about 3 feet down to the thinnest possible parting between two beds of rock. Some of those between the higher beds are undoubtedly contemporaneous detrital sediments [1] and appear to indicate shallow-water conditions; others, though consisting of sedimentary material, were probably deposited along solution planes subsequently to the formation of the limestone;

[1] Many, perhaps all, of the tuffs of Derbyshire are sediments, but, to avoid ambiguity, the use of the word in this paper is confined to detrital deposits, the waste of a land-surface.

whilst a few of the thinnest partings consist for the most part of beautiful, minute, prismatic crystals of quartz without admixture of any 'clay-substance'. All these beds are comparatively thin, not exceeding an inch or two, as a rule, and often much less.

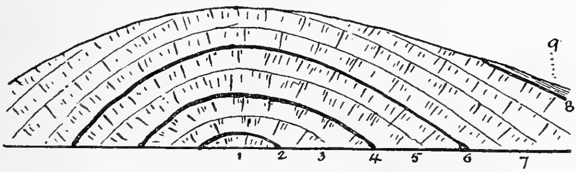
The object of the present paper is, however, to discuss the origin of the thicker clay-bands, which have already received a certain amount of attention at the hands of geologists, but which differ considerably in structure from any of the foregoing beds.

Field Relations.

The limestone of the Crich inlier forms part of the anticlinal fold which trends northward from Belper to Ashover, and its northern portion lies about 3 miles south-east of the main limestone *massif* at Matlock.

There are four distinct beds of these clays exposed in the inlier, and they may all be seen in the face of Cliff Quarry, situated under the summit of Crich Hill. The accompanying section shows their positions relatively to each other and to the limestone.

N.W. S.E.



Diagrammatic section through Crich Hill.

		Feet.
9.	Thin-bedded blue limestone, with chert, about	12
8.	First Clay-band	1
7.	Massive limestone, white to grey	70
6.	Second Clay-band	1 to 3
5.	Massive limestone, white to grey	46
4.	Third Clay-band	6 in. to 1
3.	Massive limestone, white to grey, blue near base, about	50
2.	Fourth Clay-band	6 in. to 1
1.	Massive limestone, light blue to grey, of which there are seen in the quarry	15

The Geological Survey memoir, *North Derbyshire*, 2nd ed., 1887, gives the thickness of bed No. 9 as 150 feet (p. 82), which is an obvious error.[1] The total thickness of the thin-bedded blue limestone, above the first clay-band, probably does not exceed 65 feet anywhere in the inlier. I have taken the thickness of bed No. 7 from the same memoir (p. 82), which entirely omits bed No. 8, although it is at least a foot thick in Cliff Quarry, but now much overgrown.

The first and second clay-bands are also exposed in Hilt's Quarry in the southern part of the inlier, and a clay-band, which is probably the first, is well seen in a quarry known as the 'Old Quarry', a short distance south-east of Hilt's Quarry.

[1] Cf. C. B. Wedd, Geol. Surv. Mem., Explanation of Sheet 125, 1908, p. 18.

The clays consist of stiff, plastic material, containing much moisture when first exposed, generally of a bluish-grey colour, and frequently with ochreous upper and lower surfaces, the variations in colour being apparently due to varying quantity of iron oxides. The central portion of the second clay, where exposed in Cliff Quarry,[1] is black and friable, but it does not show these features elsewhere. Minute cubes of pyrites are sporadically abundant throughout the clays.

With the exception of the first, which is generally covered by thin-bedded rock, all the clay-bands are intercalated between massive beds of limestone, without any gradation from limestone to clay, above or below.

After careful examination I have been unable to find any traces of organic life in these clays, with the exception of the black central portion of the second clay-band where exposed in Cliff Quarry.

The surface of the rock below the clay-bands is always found to be hummocky or mammillated, and not infrequently worn into deep furrows and holes, much resembling 'pot-holes', which are always filled with the clay.

Very similar clays, or 'way-boards' as they are called by miners, a term adopted by geological writers as far back as Whitehurst (1778), are frequently seen in other parts of the limestone of Derbyshire, and have been long recognized by their field relations to be decomposed toadstone. Thus, Farey (1811) says: "In many places it [toadstone] appears, both in deep Mines and at its basset, as a plastic Clay, often of a bluish grey colour, where the numerous Meers or Cattle-Ponds of this district occur upon its basset edge, . . ."[2]

Microscopic Structure.

A process of careful levigation and microscopic examination of their heavier constituents, after removal of the finer mud or 'clay-substance', show that these clays contain little or no quartz, but a fair amount of decomposing felspar, chloritic material, and sometimes abundant pyrites in minute cubes. Thin sections of material from all the exposures named above appear to bear out the same result. Owing to the mass of opaque matter it is not always easy to identify the minerals, but chloritic and felspathic material are seen, with perhaps a little secondary quartz. One of the sections, that of a specimen of the second clay-band from Hilt's Quarry, is especially interesting, in that it shows radiating aggregates giving a black cross in polarized light of a secondary mineral formed in the clay, which I have not been able to identify. It may perhaps be epidote.

Chemical Composition.

Below are given analyses of the clays and also, for purposes of comparison, of typical Derbyshire lavas decomposed to clay. The resemblance is striking, but by no means conclusive as to the origin

[1] Cf. H. H. Arnold-Bemrose, "A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire": Proc. Geol. Assoc., vol. xvi, p. 177, 1899.

[2] *General View of the Agriculture and Minerals of Derbyshire*, vol. i, p. 278.

of the clays. It would be easy to quote analyses of true sediments bearing an equal resemblance to these in their main features. There is, however, one point worth noting. No carbon, either free or in the form of hydrocarbons, was found in any of the clays under discussion.

Summary and Conclusions.

The first and second of these clay-bands have been considered by recent geological writers to be of sedimentary origin, as will be seen from the following references. Of the third and fourth bands I have found no mention by any writer.

The Geological Survey memoir, *North Derbyshire*, 2nd ed., 1887, refers as follows (p. 82) to the second clay-band in Cliff Quarry and the underlying limestone: "The upper surface [of the underlying limestone] is very curiously water-worn into furrows and pot-holes, some of the latter being as much as two feet deep.[1] We have already noticed that the surface of the limestone beneath a toadstone bed is sometimes marked in the same way, and supposed it to have been done by water, charged with carbonic acid, trickling along between the beds.[2] The clay-band holds about the same position in the series as the toadstone at Ashover and the first toadstone at Matlock, but it has not in the least the look of a decomposed lava or ash."

It is difficult to understand the last statement, except as regards the central portion of the second clay where it is black and friable as above stated. Many of the clays, which are recognized as decomposed toadstone, in the limestone of Derbyshire are remarkably similar in the field to the clays under discussion.

Mr. C. B. Wedd, in the Geological Survey memoir, Explanation of Sheet 125, 1908, p. 18, states that "the white limestone [in the inlier] includes occasional bands of shale two feet thick or more"; which can only refer to these clay-bands. Again (p. 19), he describes the clay-band exposed in the Old Quarry as "a bed of ochreous marl about three feet thick", and (p. 20) the first clay-band, where seen in Hilt's Quarry, as "a bed of shaly marl of which the top is level".

I venture to think that the following features, described above, are difficult to reconcile with the sedimentary view:—

1. The abrupt transition from a clay, 2 or 3 feet in thickness, to massive limestone which was evidently laid down in deep and clear waters, both above and below the clay (except as regards the thin-bedded limestone above the first clay).

2. The absence of organisms (microscopic or otherwise) except in one special instance mentioned above.

3. The absence of original clastic quartz—an invariable and generally abundant constituent of true sedimentary clays—the waste of a land-surface.

4. The absence of carbon, either free or in the form of hydrocarbons, of which all sedimentary clays appear to possess a proportion, frequently a very minute one. This constituent is often held in

[1] 'Pot-holes,' up to 6 feet in depth, have recently been exposed below the clay-band in the Old Quarry.

[2] Cf. H. H. Arnold-Bemrose, op. cit., p. 204. Also "The Toadstones of Derbyshire": Q.J.G.S., vol. lxiii, p. 253, 1907.

solution, and is derived, as may be supposed, from the organic life of the waters which bore such clays to their resting-place.

5. The frequent local presence of minute cubes of pyrites. This mineral appears to be always of secondary origin in sedimentary clays, and is supposed to be due to the reducing action of decaying organic matter, sometimes through the agency of enzymes, on solutions of ferrous sulphate in the sea.[1] Here we have no organic matter to set up the reaction.

On the other hand, the great similarity in appearance of these clays, in the field, to clays resulting from the decomposition of toadstone, is suggestive of volcanic origin. The features named above, as lending no support to the sedimentary view, may perhaps be held to favour this suggestion.

The field relations with regard to the country rock, the absence of original clastic quartz and carbonaceous material, and the presence of pyrites are features which these beds share with other clays in the county which are recognized as decomposed toadstones.

It must be admitted that the microscopic structure does not give much positive evidence in favour of the volcanic view, but I have found nothing on any of the slides prepared from these clays to negative that view. In these thin beds, saturated with percolating carbonated waters, decomposition would probably proceed so far that most of the original minerals in the basalt or tuff from which they might be derived would be destroyed. It appears probable, however, that in the initial stages of the process, the ferro-magnesian constituent would be converted into the chloritic material seen on the slides, and silica would be liberated by the decomposition of the felspars, so that the presence of secondary quartz can be easily explained.

Further suggestive evidence may be mentioned.

The 'pot-holes' referred to above are, so far as I am aware, only found elsewhere below a toadstone bed, and there seems no reason why there should be an exception to this rule in the Crich area.

A bed of lava is known to exist in the limestone of Crich Hill "at depths varying from 180 to 480 feet", [2] and this again indicates that the area was well within the range of Carboniferous volcanic activity.

There remains a difficulty to be faced, viz. the presence of fossils in a part of one of the exposures already alluded to. Dr. Arnold-Bemrose describes the second clay-band, where exposed in Cliff Quarry, as "a bed of black shale containing a few fossils".[3] It has been mentioned above that the central portion of this bed is here black and friable, in which respect it differs from the other clays, and it undoubtedly contains a few fragmentary traces of fossils which are always, so far as my observation goes, so badly preserved as to be

[1] Cf. H. A. Miers, *Mineralogy*, 1902, p. 328; also G. A. J. Cole, *Rocks and their Origins*, 1912, pp. 84, 85.

[2] H. H. Arnold-Bemrose, "The Toadstones of Derbyshire": Q.J.G.S., vol. lxiii, p. 266, 1907.

[3] "A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire": Proc. Geol. Assoc., vol. xvi, p. 177, 1899.

incapable of identification. The black colour is no doubt due to the presence of ferrous sulphide. Minute crystals of selenite are abundant, suggestive of the action of decomposing pyrites on carbonate of lime.

It is not easy to explain the presence of these fossils in this limited exposure, but their fragmentary condition and the entire absence of carbonaceous matter in the bed seem to indicate a derivative origin. One or two suggestions may perhaps be permitted. If this black central portion of the bed represents a local shower of ash, following a temporary cessation of the eruption of lava, the presence of fossils would present no difficulty. On the other hand, cases could be cited in which a rapidly cooling lava-flow has embedded remains without entirely destroying them, and it seems not impossible that this may have happened here.[1] Whatever the solution, the great difference between this portion of the bed and its other exposures, in structure, chemical composition, and appearance, would seem to indicate some difference in origin.

Another objection which may be raised against the hypothesis of volcanic origin is the absence of alteration in the rock below the clays. It must be borne in mind that such thin lava-flows would cool very rapidly on the sea-floor, and in other parts of the county very little and sometimes no alteration has been effected in the rock in contact with beds of basalt much thicker than these clays.[2]

Dr. Arnold-Bemrose has kindly called my attention to the fact that the view set forth in this paper is not of recent origin. Thus, sixty years ago Sir H. de la Beche wrote as follows: "Although there are clays amid the limestones in the relative positions of the igneous rocks, and some of these seem clearly little else than such rocks in a highly-decomposed state, retaining the arrangement of their component mineral substances, as, for example, *at the isolated boss of limestone at Crich* [italics mine], . . . it would scarcely be safe to conclude that all lying nearly in the same general geological levels were so, inasmuch as some of them may be clays of another character. Care on this head is rendered necessary by finding a clay—a true under-clay of the coal-measure kind—supporting a thin bed of impure coal in the higher part of the limestone series near Matlock Bath."[3]

It is an interesting circumstance that, in a quarry near Matlock Bath, there is at the present time a bed of clay exposed, supporting a thin bed of black shale with *Pterinopecten papyraceus*, and occasionally a thin coal is found on the clay. There can be little doubt that these are the beds referred to by Sir H. de la Beche. I have examined this clay, and although in external appearance it much resembles a fireclay, in microscopic structure it is quite different and agrees very closely with the clays described above. I have little doubt that it is of igneous origin. The rock above is thin-bedded, with thin partings of unmistakable detrital structure between the beds, so that no doubt a shore-line was not far distant, and thus the presence of the shale and coal is not so anomalous as it otherwise would be.

[1] Cf. Lyell, *Principles of Geology*, 12th ed., vol. ii, p. 516, 1875.
[2] Cf. Geol. Surv. Mem., *North Derbyshire*, 2nd ed., 1887, p. 20.
[3] *Geological Observer*, 2nd ed., 1853, p. 560.

Nine years earlier than the date of the above quotation from De la Beche, John Alsop makes the following significant statement: [1] "In a section of Crick [Crich] cliff, what is at one shaft a thin bed of clay a foot thick, becomes within a short distance fourteen feet thick, *and contains large nodules of compact toadstone* [italics mine], . . ."

I have also been informed that the late A. H. Stokes, F.G.S., H.M. Inspector of Mines, held the opinion that the clays above described were of igneous origin.

If, then, these clays represent lava-flows, or possibly in some cases tuffs, the interesting question follows, where was the vent situated from which they were erupted? With the Editor's permission I propose to discuss this question in a subsequent paper.

ANALYSES BY MR. ERIC SINKINSON.

	First Clay-band (blue central portion), Hilt's Quarry.	First Clay-band (ochreous margin), Hilt's Quarry.	Second Clay-band, Hilt's Quarry.	Second Clay-band (black central portion), Cliff Quarry.	Third Clay-band, Cliff Quarry.	Fourth Clay-band, Cliff Quarry.	Lower Lava of Matlock Area (Clay), Hoptonwood Quarry, near Wirksworth.	Upper Lava of Matlock Area (Clay), Salter's Lane, Matlock.
SiO_2 . . .	46·66	48·60	47·50	58·46	56·61	51·04	47·83	47·11
Al_2O_3 . . .	24·76	24·23	29·62	22·34	31·98	31·63	22·74	25·99
F_2O_3 and FeO	8·82	21·99	4·48	—	0·47	0·30	4·76	9·87
FeS_2 . . .	—	—	—	1·19	—	—	5·02	—
FeS . . .	—	—	—	1·02	—	—	—	—
MgO . . .	2·72	trace	1·35	1·46	1·02	1·22	2·50	3·23
CaO . . .	1·97	0·42	0·96	0·56	1·07	1·20	1·19	1·95
Na_2O and K_2O	2·02	0·71	3·00	2·00	2·82	2·95	3·30	4·93
H_2O . . .	12·52	3·72	12·73	12·97	6·03	11·66	12·66	6·92
CO_2 . . .	0·53	0·33	0·36	—	—	—	—	—
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

V.—OUTLINES OF THE GEOLOGY OF MOZAMBIQUE.

By ARTHUR HOLMES, B.Sc., A.R.C.S., F.G.S., and D. A. WRAY, B.Sc., F.G.S.

IN 1911 Mr. E. J. Wayland, F.G.S., and the authors visited the Portuguese East African province of Mozambique in the interests of the Memba Minerals, Ltd. The country was very little known geographically, and except along the coast, it was a *terra incognita* to geologists. We hope in due course to publish a detailed account of our observations, but as it will be some time before this can be completed, it seems advisable to give a short résumé of the salient geological features of the territory. It is hoped that these results

[1] Brit. Assoc. Report, 1844, Trans. Sections, p. 52.

will prove of interest to students of East African geology, especially in their bearing on problems of theoretical interest concerning the geological history of that portion of the globe.

With the exception of a narrow coastal strip consisting of Cretaceous and Tertiary sediments with some volcanic rocks, the whole country consists of a complex of gneisses and other foliated rocks intruded upon by massive igneous rocks and their attendant dykes. Although we proceeded as far inland as latitude 37° E., no further signs of any sedimentary rocks were met with. Rocks probably of Karroo age occur immediately to the north in the Lujenda Valley, to the east in British Central Africa, and to the south in Zambesia, but in each case they owe their preservation to trough-faulting. Denudation appears to have entirely removed such formations from the surface of Mozambique. The oldest sediments lying on the metamorphic rocks are of Lower Cretaceous age, and consequently there is little direct geological evidence for the age of the complex. However, judging from their lithological features, the intricacy of their structure, and their similarity to corresponding fundamental rocks in other parts of the globe, we feel justified in assigning these rocks to the Archæan. Particularly striking is their resemblance to the rocks of British Central Africa, British and German East Africa, and Madagascar; for this consists in not only their detailed field characteristics and the peculiar 'inselberge' landscape they give rise to, but also in their mineral and chemical characters.

The country inland from Mozambique gradually changes in type. After the low-lying sedimentary zone is crossed the surface is that of a gently rising plateau from which many isolated peaks and hills arise. They produce a peculiar type of topography which also occurs in German East Africa, where it has been examined and its origin discussed by Bornhardt.[1] In Northern Nigeria[2] the scenery is very similar, and this type appears to be a marked characteristic of the gneiss and granite regions of Africa. Fantastic peaks, rocky domes, and cone-shaped hills rise precipitously from the plateau, like islands surrounded by a verdant sea of forest. By their aggregation lofty mountain blocks and ranges are formed, and one of the most extensive of these in Mozambique is the Chica range, which stretches for 20 miles in a N.N.E. and S.S.W. direction, about 150 miles from the coast. Further west are the great massifs of Ribaue and Inago, rising to 5,000 and 6,000 feet respectively, whilst in the western limit of the country rise the famous Namuli Peaks, so long conjectured to be of volcanic origin, but consisting of a huge block of granite and gneiss with conical peaks, and rising to 8,000 feet above sea-level. These four mountain groups define the watershed of the territory, and from them the rivers flow north, south, and east.

In the metamorphic series of Mozambique there are but few representatives of true schists. From the north-east of the territory,

[1] W. Bornhardt, *Die Oberflächengestaltung und Geologie Deutsch-Ost-Afrika*, Bd. vii, Berlin, 1900; see especially pp. 34–9.

[2] J. D. Falconer, *Geology and Geography of Northern Nigeria*, London, 1911; see especially plates v, vii, and xvii.

approaching the mouth of the Lurio or Luli River, chlorite- and mica-schists are recorded, with thin bands of hæmatite- and graphite-schists. They appear to be isolated remnants of a formation now mostly removed by denudation. Dr. Voit has remarked that a schistose series is preserved more typically in the south of the continent, while towards the Equator gneisses are found to be more important. In each case the metamorphic rocks are accompanied by intrusive granites. Our investigations fully bear out Dr. Voit's observations.[1]

The dominant rock of the country is a grey biotite gneiss, often containing hornblende, which varies from coarsely banded varieties to finely foliated types. The former contain granular bands of quartz and felspar, and it is often impossible to distinguish them from pegmatite intrusions. With the development of patches of felspar in place of bands the rock passes into an augen-gneiss, and this in turn may sometimes be traced into a slightly porphyritic granite, with little sign of any directive structure. The fine-grained type on the other hand merges into mica-schist, though it is but rarely that the latter is found. Associated with these rocks are lenticular masses of hornblende-gneiss and, to a less extent, of garnet and epidote-bearing rocks. Quartzites and crystalline limestones are nowhere common in this territory, but several bands intercalated with the gneiss have been noted, sometimes of considerable thickness. The gneisses are the oldest rocks of the country, and into them granite intrusions have penetrated at two distinct periods, and perhaps also at others. The granite rises in great domes, often with steep sides, and from them the overlying gneiss dips away in every direction. By exfoliation thin flakes of gneiss are split off parallel to the foliation planes, and in this way the hills tend to retain the outline of the granite core, a favourable condition for the production of the 'inselberge' landscape. The granites are notably poor in ferromagnesian minerals, and present a contrast to the gneisses with their much higher proportion of biotite and hornblende. Otherwise the mineralogical constituents are very similar in the two cases. Felspar is the most abundant mineral, microcline[2] being constantly present, as is characteristic of all the old granites of Central and South Africa. Associated with the granites are enormous numbers of pegmatite dykes, sometimes as much as 10 feet across, but more usually not as many inches. Iron-ores are very commonly present, hæmatite and magnetite being everywhere very plentiful. Basic dykes also enter into the architecture of the complex, but they are sparingly distributed, and of their genetic relations and age nothing is yet known.

The coastal strip of Cretaceous rocks has an average width of 10 to 12 miles, but the strata do not form a continuous outcrop, and at Memba Bay the coarse Archæan gneisses reach the sea in rugged sea-cliffs fringed with recent coral-reefs. The Cretaceous beds have a very gentle dip towards the south-east, and seem to have been subjected to little movement since their deposition. Three main

[1] F. W. Voit, Trans. Geol. Soc. South Africa, vol. x, p. 92, 1907.
[2] C. B. Horwood & A. Wade, Geol. Mag., Dec. V, Vol. VI, p. 459, 1909.

groups or series are provisionally recognized. In descending order they are :—

3. Conducia Beds.
2. Mount Meza Beds.
1. Fernão Vellozo Beds.

Of these beds only the Conducia Beds[1] have been hitherto noticed.

The Fernão Vellozo Beds are admirably exposed in many coast and inland sections from Memba southwards to the district around Fernão Vellozo or Masasima harbour. A little south of the harbour, near Chief M'shilipo's kraal, they consist of an alternating series of limestones and shales, and in these we fortunately obtained a small assemblage of fossils which show distinct Uitenhagian characters, and conclusively determine the beds in question to be of Neocomian age.

The second series, the Mount Meza Beds, consist predominantly of sandstones with some calcareous bands. They form several flat-topped hills in the neighbourhood of the coast, Mount Meza itself being over 1,000 feet above sea-level. Judging by the fact that they conformably succeed the Fernão Vellozo Beds, and also underlie the Conducia Beds, they are in all probability of Aptian and Albian age. An Aptian fauna along this coast has already been described by Professor Kilian[2] from so near a locality as Delagoa Bay.

The highest Cretaceous Series (3), the Conducia Beds, are well exposed in Conducia Bay, a few miles north-west of Mozambique Island, and a description of their fauna has been contributed by Choffat[3] to the Portuguese Geological Commission. Choffat referred these beds to the Upper Cretaceous, ranging from Vraconian to Senonian, and he pointed out their close affinities with the Southern Indian development (Ariyalur and Utatur stages).

The discovery of these Cretaceous deposits along the Mozambique coast, and exactly opposite the Island of Madagascar, shows that probably the Indo-African land connexion had already been broken in early Cretaceous times.[4]

Above the Cretaceous, and resting with a slight unconformity on them, comes a series of beds referred by Sadebeck[5] to the Upper Eocene or Oligocene. They have yielded some corals and Foraminifera. They occur in two facies; one a poorly consolidated limestone, and the other a hard sandstone frequently conglomeratic. The limestones on Mozambique Island weather in a peculiar manner, giving rise to deep solution pits circular in outline.

[1] P. Choffat, "Contributions à la connaissance géologique des colonies Portugaises de l'Afrique: Le Crétacique de Conducia": Comm. Serv. Géol. Portugal, Lisboa, 1903.

[2] Kilian, "Sur la présence de l'étage Aptien dans le sud-est de l'Afrique": Compt. Rendus, cxxxv, No. 1, pp. 68–71, 1902, and Bull. Soc. Géol. France, ser. iv, ii, p. 358, 1902.

[3] P. Choffat, "Contributions à la connaissance géologique des colonies Portugaises de l'Afrique: Le Crétacique de Conducia": Comm. Serv. Géol. Portugal, Lisboa, 1903.

[4] For further discussion of this problem see especially F. L. Kitchin, "Invertebrate Fauna of the Uitenhage Series," Annals South African Museum, vol. vii, pt. ii, pp. 51–6, 1908.

[5] A. Sadebeck, "Geologie von Ost-Afrika" in Von der Decken's *Reisen in Ost-Afrika*, Leipzig, 1879.

Of great interest are the lavas so well developed along the coastal strip and hitherto not described or referred to elsewhere. Basaltic lavas were extruded over a large area, but denudation has now reduced them to scattered remnants.

Amygdaloidal basalts, clearly the result of fissure-eruptions, are found in a zone never far from the coast, and stretching northwards from Mokambo Bay for some 20 miles. Associated with them, and representing the ducts up which the molten magma found its way to the surface, are numerous dykes and sills of dolerite. Pebbles of agate and jasper, derived from the cavities in the basalt, are found far to the west and north of the present exposures, and indicate roughly the former extensions of the flows. Besides quartz and chalcedony, zeolites of various types are found filling the amygdules. The basalt and dolerite differ only in the coarser crystallization of the latter and its relative freedom from vesicles. Olivine appears to be entirely absent, its place being taken by the orthorhombic pyroxenes. In this respect the rocks differ from other East African basalts, for in the latter olivine is generally a noteworthy constituent. The flows lie indiscriminately on the Archæan gneisses, and on the Cretaceous and Tertiary sediments, while the dykes and sills intrude through the same formations. Where they are in contact with the Cretaceous limestone, this has been transformed into a crystalline aggregate within a few inches of the contact.

Along the coast and for some distance inland are found numerous raised beaches lying at heights up to 25 feet, while the whole coast is fringed with coral reefs. These deposits afford further proof of the recent uplift of the East African coast, evidences of which have also been met with both to the south and north. Another indication is found in the rejuvenation of the streams which, thus endowed with greater energy, have been enabled to cut gullies in the gravels and sands of an earlier epoch. The superficial deposits which are now being dissected are the products of disintegration of the older rocks. These we found to consist in general of two types: the first, enveloping the hills, and due in the main to the disintegration of rock in situ, and the second found in the plains and clearly showing evidence of having been transported by water-action.

The decomposition of rocks in situ gives rise to two widely different varieties of residual deposits. The one consists of kaolin, the other of laterite, and in most cases angular particles of quartz are present. The former type of alteration calls for little comment, but it may be observed that the gradual transition of hard rock into soft china-clay could easily be traced in the field, suggesting that surface action alone had brought about the change.

A quartzose laterite is the more usual superficial formation. In general it forms hard, brown, slaggy-looking masses, with concretions of iron-ore containing numerous angular fragments of quartz. The rock is penetrated by cavities which may be partly occupied by a powdery ferruginous earth. The laterites usually occur in bands running parallel to the strike of the gneiss, and often these lie near the crest of low ridges which follow the same direction. They also occur near the sides of small watercourses, of which the majority dry up during several months of the year. In the beds of these streams concretions of limonite appear to be forming at the present time. Similar concretions are found in the alluvial sands, and in many places a ferruginous cement has hardened the upper layers of the latter. These phenomena are probably due to the evaporation of iron-bearing solutions brought near the surface, with consequent deposition of the hydrated oxides. The origin of laterites is a much-discussed problem, but we believe that many of the Mozambique varieties have originated in this way, a view in support of which we hope to present fuller evidence on a future occasion.

VI.—The Carboniferous Succession in the Forest of Dean Coalfield.

By T. Franklin Sibly, D.Sc., F.G.S., Lecturer on Geology in King's College, London.

A. Introduction.
B. The Lower Carboniferous Rocks.
C. The Intra-Carboniferous Unconformity.

A. Introduction.

The following preliminary account is presented as the result of several weeks of field-work on the northern and eastern margins of the Forest of Dean Coalfield, carried out partly in 1910 and partly in the present year. The area which I have examined lies almost wholly within Sheet 43 S.E. of the 1 inch Geological Survey Map (Old Series), but extends a short distance into Sheet 43 S.W. In portions of this area, the Lower Carboniferous rocks have been studied in detail and mapped. The Coal Measures, however, have as yet been examined only in their relation to the Lower Carboniferous strata. The present communication is, therefore, confined to a demonstration of the important unconformity which exists between the Coal Measures and the Lower Carboniferous rocks, together with a brief description of the latter. I am continuing my investigations, and I hope to give at some future date a more comprehensive account of the geology of the coalfield. In the meantime, the following outline may be of interest.

The Carboniferous succession in the north and east of the coalfield comprises the following members:—

Lower Carboniferous.

1. *Carboniferous Limestone Series.* The strata of this division succeed the Old Red Sandstone with perfect conformity, and are themselves overlain conformably by

2. *The Drybrook Sandstone.* A thick sandstone formation, the 'Millstone Grit' of previous writers.

Upper Carboniferous.

3. *Coal Measures.* As will be shown, the strata of this series lie unconformably, and in some places with great discordance of dip, upon the Lower Carboniferous rocks (2) and (1).

B. The Lower Carboniferous Rocks.

Carboniferous Limestone Series.

Mr. E. Wethered has given some description of the strata of this series in three papers.[1] More recently Dr. A. Vaughan has given[2] an outline of the sequence in the Mitcheldean district, on the north-eastern margin of the coalfield, and a correlation of this sequence with the Avonian of the Bristol area. My own studies confirm Dr. Vaughan's conclusion that the top of the Carboniferous Limestone Series in the Forest of Dean lies far below the summit of the Avonian; but the features of the series as I have observed them differ in several important particulars from those outlined by him.

The Carboniferous Limestone Series is readily capable of a three-fold subdivision on lithological grounds. The following table gives the approximate thickness of each subdivision in the Mitcheldean district, and a correlation with the zones of the Avonian.

	Avonian Zones.
(c) *Whitehead Limestone*, 20 to 50 feet.	C
(b) *Main Limestone*, about 320 feet . . .	Z
(a) *Lower Limestone Shales*, about 180 feet . . .	K

Lower Limestone Shales. This subdivision represents the *Cleistopora*-zone (K), and probably includes the base of the *Zaphrentis*-zone (Z) also. It comprises limestones and shales of very varied character, and passes down conformably into the sandstones which form the top of the Old Red Sandstone. Its lowest member is a thick band of limestone, often oolitic and gritty. At the junction with the Old Red Sandstone an alternation of limestone with sandstone occurs throughout a small thickness of beds, but there is no appreciable development of a transition-series comparable, either faunally or lithologically, with the *Modiola*-phase at the base of the Avonian in the Avon section. The subzones K_1 and K_2 can be distinguished, but in each sub-zone the faunal assemblage presents considerable differences to the corresponding assemblage in the Bristol and Mendip areas.

An important feature of the *Cleistopora*-zone in this area is the strong development of *Modiola*-phase (calcareous lagoon-phase) deposits in the middle and upper portions of the zone. These deposits are of exceedingly varied lithological character. As regards

[1] "On the Lower Carboniferous Rocks of the Forest of Dean, as represented in Typical Sections at Drybrook": Q.J.G.S., vol. xxxix, p. 211, 1883. "On the Structure and Organisms of the Lower Limestone Shales, Carboniferous Limestone, and Upper Limestones of the Forest of Dean": Geol. Mag., Dec. III, Vol. III, p. 530, 1886. "On the Lower Divisions of the Carboniferous Rocks in the Forest of Dean": Proc. Geol. Assoc., vol. x, p. 510, 1887–8.

[2] Q.J.G.S., vol. lxi, pp. 251–2, 1905.

palæontological characters, they present the usual abundance of ostracods and occurrence of modioliform lamellibranchs; but their most striking feature is the abundance of *Serpula*-like annelids, or *Mitcheldeania*-like algæ, or both these fossils, in certain bands of calcite-mudstone. The *Serpulæ* often occur in the form of large, fasciculate masses of tubes, but exhibit a variety of forms.

Main Limestone. This is composed in bulk of dolomites and dolomitic limestones, with a local and variable development, in the upper part, of crinoidal or oolitic limestones which have escaped dolomitization.

The lower, and major, portion belongs to the *Zaphrentis*-zone, and consists for the most part of finely crystalline dolomites, red, yellow, or grey in colour. Fossils are so scarce in these beds that the sub-zones Z_1 and Z_2 have not yet been distinguished.

The upper part is of *Syringothyris* age (C), and belongs mainly, at least, to the sub-zone C_1. Essentially, this upper portion of the Main Limestone consists of a series of crinoidal limestones capped by a few beds of coarsely crystalline dolomite. The crystalline dolomites, which immediately underlie the Whitehead Limestone, are persistent, and the lower beds of the crinoidal limestone-series are always dolomitic; but the intervening beds vary considerably in character, both from bed to bed in vertical sequence, and also when traced laterally. The variations in these intervening beds are chiefly due to (*a*) the very variable extent to which dolomitization has affected the rocks, and (*b*) the sporadic development of oolitic structure. In some localities all the beds are more or less strongly dolomitized. Elsewhere the dolomitization is distributed irregularly, so that beds of large collective thickness have locally escaped dolomitization. Important deposits of hæmatite occur in this series of limestones; and the maximum amount of dolomitization of the rocks is found in those localities where the hæmatite-deposits are well developed. On the evidence collected up to the present, it appears that in this whole series of crinoidal limestones a certain amount of 'contemporaneous' dolomitization, almost confined to the lower beds, has been followed by extensive but irregularly distributed 'vein-dolomitization' connected with the formation of the hæmatite-deposits.

Whitehead Limestone. This small subdivision is of special interest and importance, inasmuch as it constitutes a well-marked *Modiola*-phase. The rocks composing it are chiefly limestones, with subordinate calcareous clays which often contain numerous limestone-nodules. Locally, some of the beds are dolomitized. The limestones are very variable in character, but among them finely oolitic rocks and calcite-mudstones of chinastone type predominate. *Mitcheldeania*-nodules and (?) *Girvanella*-nodules are common in many of the limestones, and sometimes so abundant as to form the bulk of the rock. A certain amount of fine quartz-sand occurs in all the beds; and the occasional intercalation of bands of calcareous grit foreshadows the oncoming of the Drybrook Sandstone, into which formation the Whitehead Limestone passes up conformably.

I have discovered no fossil evidence to support Dr. Vaughan's correlation of the Whitehead Limestone with the Upper *Seminula*-zone.[1] Indeed, I have as yet found no determinable corals or brachiopods in this subdivision; and at present I would only point out that, on the evidence of the underlying beds, the Whitehead Limestone represents some horizon not far removed from the summit of the *Syringothyris*-zone. The study of the south-western margin of the coalfield will probably throw light upon this question; for in proceeding south-westward from Mitcheldean we approach the Chepstow area, in which the *Seminula*-zone is finely developed.[2]

Drybrook Sandstone.

This formation has yet to be studied in detail. It is composed very largely of pure quartz-sandstones, often coarse-grained and friable. Conspicuous bands of quartz-conglomerate occur; some clays and shales are intercalated with the sandstones; and some hæmatite deposits are developed. The thickness of the beds at their outcrop in the neighbourhood of Ruspidge, south of Cinderford, is at least 600 feet.

Mr. Wethered has recorded[3] a *Lepidodendron* "allied to *L. griffithii*, Brongn." from the lower beds of this formation at Drybrook. No other determinable fossils have yet been recorded.

The Lower Carboniferous age of the 'Millstone Grit' in the Mitcheldean district was demonstrated by Dr. Vaughan[4] in 1905. The term Drybrook Sandstone—from Drybrook, near Mitcheldean, Gloucestershire—is now proposed instead of 'Millstone Grit'. We have seen that the base of the Drybrook Sandstone lies conformably upon limestones whose horizon cannot be far removed from the top of the *Syringothyris*-zone, and we may conclude that the whole of this formation is older than the Millstone Grit proper.

C. The Intra-Carboniferous Unconformity.

Mr. E. A. Newell Arber has proved conclusively that the Coal Measures of the Forest of Dean belong mainly, if not wholly, to the Upper Coal Measures.[5] I find that *the relation of the Coal Measures to both the Carboniferous Limestone and the Drybrook Sandstone is one of pronounced unconformity.*

On the eastern margin of the coalfield, the strata of the Carboniferous Limestone and Drybrook Sandstone dip steeply westward, and consequently their outcrop forms only a narrow band. Between Mitcheldean on the north and Ruspidge on the south, that is, throughout a distance of about 4½ miles, the superincumbent Coal Measures, which dip westward at a small angle, rest upon the Drybrook Sandstone. South of Ruspidge, however, the Coal Measures overstep eastward into the Carboniferous Limestone and conceal the Drybrook Sandstone. The transgression is gradual at first, but near Howbeach Colliery, about 2 miles south of

[1] Q.J.G.S., vol. lxi, p. 252, 1905.
[2] A. Vaughan, ibid., p. 251.
[3] Q.J.G.S., vol. xxxix, p. 215, 1883.
[4] Q.J.G.S., vol. lxi, p. 252, 1905.
[5] E. A. Newell Arber, "On the Fossil Flora of the Forest of Dean Coalfield (Gloucestershire), and the Relationships of the Coalfields of the West of England and South Wales": Phil. Trans. Roy. Soc., vol. ccii, B, pp. 233–81, 1912.

Ruspidge, the base of the Coal Measures passes rapidly eastward across the remainder of the Carboniferous Limestone Series, on to the Old Red Sandstone. The Carboniferous Limestone remains concealed by Coal Measures for a distance of some 3 miles south of Howbeach Colliery; it reappears near Lydney, at the southern end of the coalfield.

Close to Howbeach Colliery, in the gorge of Blackpool Brook, an old quarry shows the unconformable junction of Coal Measures and Carboniferous Limestone. The quarry-face shows dolomites belonging to the Main Limestone, dipping north-westward at about 60°, overlain by Coal Measure sandstones which dip westward at a small angle.

On the northern margin of the coalfield, west and north-west of Drybrook, the beds of the Carboniferous Limestone Series, being gently inclined, cover a large area. Not far west of Drybrook, the Drybrook Sandstone is overstepped by the Coal Measures. Farther west, beyond Ruardean, the Coal Measures rest upon the Main Limestone; while to the north of Ruardean, across the valley, a large outlier of Coal Measures reposes directly upon the Lower Limestone Shales at Howle Hill.

Some of the features just described have been noticed by earlier writers. In particular, the interruption of the Limestone-outcrop on the south-eastern border of the coalfield, between Howbeach Colliery and Lydney, was noticed by Buckland and Conybeare,[1] who attributed it to a fault; and the same phenomenon was discussed and very clearly illustrated by Maclauchlan.[2]

H. D. Hoskold, writing in 1892, stated that near Howbeach Colliery "the Pennant rocks belonging to the Lower Coal Measures rest immediately upon and are in contact with the Carboniferous Limestone".[3]

Quite recently Mr. Newell Arber, in his important paper[4] on the fossil flora of the coalfield, has discussed the relation of the Coal Measures to the underlying strata at some length. He writes as follows:—

"Reviewing the present evidence I am inclined to think that it will eventually prove that an unconformity exists a short distance below the Lower Trenchard Coal perhaps a little above the Sandstone vein of Iron Ore. In this case the greater portion of the Millstone Grits, so-called, will be found to be simply a sandy facies of the Carboniferous Limestone Series, just as the lower beds have already been shown to be by Dr. Vaughan. I imagine that, in the Forest of Dean, the Upper Coal Measures rest unconformably on an ancient floor consisting for the most part of the higher sandy beds of the Carboniferous Limestone Series, though, in some parts of the area, on Carboniferous Limestone of normal facies or even on Old Red Sandstone . . . Owing to the general absence of sections, the unconformity has not, however, been demonstrated in the field. True Millstone Grits, Lower, Middle, and Transition Coal Measures

[1] Trans. Geol. Soc., ser. II, vol. i, p. 286, 1824.
[2] Trans. Geol. Soc., ser. II, vol. v, pp. 204–6, 1837.
[3] Proc. Cotteswold Nat. F.C., vol. x, p. 135, 1892.
[4] See n. 5, p. 420.

appear to be absent in the Forest of Dean, so that the unconformity in question is of considerable importance." [1]

The unconformity between the Coal Measures and the Lower Carboniferous rocks in the Forest of Dean represents a great gap in the Carboniferous succession. The break appears to be quite as extensive as that which Mr. E. E. L. Dixon has shown to exist in the Titterstone Clee Hills,[2] and it is doubtless due to the same earth-movement. The tectonic relations of the strata in both the Forest of Dean and the Titterstone Clee Hills, show clearly that a powerful earth-movement occurred at some date between Avonian and Upper Coal Measure times.

It would be premature to attempt any discussion of the bearing of this evidence upon the general tectonic history of Carboniferous times. But in this connexion it is important to note that future research in the Bristol and Somerset Coalfields may enable us to fix accurately the date of the earth-movement in question. A feature which may prove to be of great significance is the relation of the Pennant Grit to the Carboniferous Limestone in the Clevedon and Clapton district, near Bristol. In 1905, Dr. Vaughan expressed the opinion [3] that a considerable unconformity between the Coal Measures and the Carboniferous Limestone afforded the only possible explanation of the structure of that district.

REVIEWS.

Prehistoric Remains in Cornwall.

I.—Harlyn Bay and the Discoveries of its Prehistoric Remains. By the Rev. R. Ashington Bullen, F.L.S., F.G.S. Third edition. pp. 173. Harlyn Bay: Colonel Bellers, 1912. Price 1*s*. net.

Harlyn Bay lies to the east of Trevose Head in Cornwall, the western horn of the bay being formed by the comparatively hard greenstone (proterobase) of Cataclews Point, and the eastern side by Upper Devonian Slates. The southern and south-western portions of the bay are bordered by Blown Sand, which extends to Constantine Bay, thus isolating the headland of Trevose. As remarked by Mr. Clement Reid, "At Constantine the sand drifts right across the isthmus into Harlyn Bay, where it has overwhelmed an ancient British cemetery . . . The graves at Harlyn are partly dug in blown sand, but they have been overwhelmed by a much thicker sheet of similar material." [4]

We commence with a reference to the recent Geological Survey publications, as the attention of Mr. Bullen has evidently not been drawn to them. The first edition of his work was issued in 1901,

[1] E. A. Newell Arber, "On the Fossil Flora of the Forest of Dean Coalfield (Gloucestershire), and the Relationships of the Coalfields of the West of England and South Wales": Phil. Trans. Roy. Soc., vol. ccii, B, pp. 270, 277, 1912.

[2] Geol. Mag., Dec. V, Vol. VII, p. 458, 1910.

[3] Q.J.G.S., vol. lxi, p. 228, 1905.

[4] "Geology of the Country around Padstow and Camelford," 1910, p. 89, and Geological Survey Map, No. 335, 1910.

the second in 1902, and in the present volume he states that he incorporates the later discoveries made up to 1905, since which but little has been done.

The general section of the Harlyn Bay deposits is given by Mr. Bullen as follows:—

Blown shell-sand	12–15 feet.
Dark sand with slate implements, etc. . .	6 inches.
Cists with interments	2–4 feet.
Rubble and clay	1 foot.

The author refers to the Neolithic implements fashioned from shells of limpet and mussel, and from slate and flint. The occurrence of flint is interesting, but the material is found elsewhere in Cornwall, and in Mr. Reid's opinion seems to have been derived from some old Tertiary deposit now beneath the sea (op. cit., p. 93).

Figures are given of the human remains found in the cists, with notes on their characters by the late Dr. Beddoe and Professor Haddon. Other vertebrate remains found in Neolithic deposits include ox (*Bos taurus* and ? *B. longifrons*), sheep, pig, horse, rabbit, and goose, identified by Mr. E. T. Newton. The marine and non-marine mollusca are also noted, and among the latter *Helix aspersa* was obtained from a kitchen-midden, and *Hygromia montivaga* (West.) from under the grave-level at Harlyn. This being a Lusitanian shell and an entirely new record for England, the author takes the opportunity of discussing the question of migration and distribution of some of the mollusca. The work is of considerable interest to geologists in connexion with the early or pre-Roman portion of the Holocene period; but we have not referred here to many objects of archæological interest, of Neolithic, Roman, and later dates, which have been brought to light by the painstaking researches of Mr. Bullen [1] and of those associated with him. A useful index completes the volume.

II.—The Geology of the South Wales Coal-field. Pt. iii: The Country around Cardiff. By Aubrey Strahan, M.A., Sc.D., F.R.S., and T. C. Cantrill, B.Sc. Second edition. 8vo; pp. viii, 157, with 13 text-illustrations. 1912. Price 2*s*.

In this new edition the memoir has been increased by ten pages and the price has been reduced by threepence. Sundry additions and corrections have been made. The useful tabular lists of the Silurian fossils from Cardiff and Usk have been omitted, perhaps on account of the ever-increasing perplexities in nomenclature; but the local lists of species are given. In the Old Red Sandstone the former 'middle series of dull-red grits and sandstones' is now termed Brownstones, and placed at the base of the Upper Old Red Sandstone; the Lower division comprises red marls with sandstones, cornstones, etc. References are made to the palæontological zones in the Carboniferous Limestone, but little work has been done in the Cardiff area, the new information relating mainly to the zonal work of

[1] [As we go to press the sad news reaches us of the sudden death of our dear friend Mr. Bullen, on August 14, when on his way to Germany.—H. W.]

Dr. T. F. Sibly in a small part of Somerset (at Worle Hill and Middle Hope) that is included in the Cardiff map. Further particulars are also given of the volcanic rocks of Somerset, of the Keuper and Rhætic beds, the Lias, and superficial deposits. Records of new well-borings are added, and the geological bibliography of South Wales and Monmouthshire has been brought up to date.

III.—The British Carboniferous Trepostomata. By G. W. Lee, D.Sc. Being vol. i, pt. iii of Memoirs of the Geological Survey of Great Britain. Palæontology, pp. 135–95 and pls. xiv–xvi. 4to. 1912. Price 3*s.*

THE Trepostomata, which form a sub-order of the Bryozoa, are abundant in Palæozoic rocks of different regions, but in their study there is "absolute need of thin sections and careful microscopical examination". Dr. Lee now distinguishes twenty-three species, of which twenty are new and three previously described. These are referred to already known genera; while one species is constituted the type of a new genus under the name *Koninckopora inflata* (de Koninck), a form referred to *Calamopora* by de Koninck, and to *Stenopora* by M'Coy. The species occur in the Lower Carboniferous rocks, and have been obtained from sundry localities in the west and north of England, Scotland, South Wales, the Isle of Man, and Ireland.

Egyptian Echinoids.

IV.—Notes sur les Échinides fossiles de l'Égypte. Par M. R. Fourtau. Bull. Inst. Égyptien, sér. v, tome v, pp. 137–76, pls. i–iv. 8vo.

OUR knowledge of the Echinoid fauna of the Upper Cretaceous is derived to a surprising degree from the discoveries that have been made in the Mediterranean region. Numerically, Echinoids are sufficiently abundant in the Chalk of Northern Europe, but their differentiation into genera and species is proportionately small when contrasted with the wealth of variety among those found in the belt of country between Algieria and Persia. Although the researches of Pomel and Cotteau, Perou and Gauthier for Algieria, of the last-named for Tunis and Persia, and of Fourtau for Egypt, are both admirable and bulky, they represent the results of but few and spasmodic expeditions when compared with the prolonged and persistent investigations that have been undertaken in Europe.

The maximum of specific differentiation in the Mediterranean Upper Cretaceous seems to have been attained by three groups of Echinoids. For the Regularia, *Cyphosoma* and its allies show the greatest variety; for the Holectypoida, *Coenholectypus*; and for the Spatangoida, *Hemiaster*. In the case of the last-named genus there have already been described a bewildering number of species, and hardly any paper dealing with the Echinoids of the region appears without some addition being made to the list.

The memoir under consideration is in some respects an aftermath of the recent paper by Dr. W. F. Hume on Secular Oscillation in Egypt (Quart. Journ. Geol. Soc., 1911), the specimens described having been largely used for the stratigraphical arguments in that work. The Cretaceous forms come from the extreme west of Egypt, partly from the borders of the Red Sea, and the Tertiary specimens from the Valley of the Nile. The latter are all derived from the Eocene Rocks, and are all Spatangoids, including one new species and one new variety. The Cretaceous species are more numerous, and give occasion for several systematic discussions of importance.

It is perhaps a sign of the times that in a systematic paper of this magnitude no new species of *Cidaris* are proposed, and it is certainly a relief for the student of the Cidaroida. A large number of Cyphosomatids, such as *Cyphosoma*, *Rachiosoma*, and *Psilosoma*, are described and figured, many being new. The last-named genus, founded by Pomel, is resuscitated after its recent rejection by M. Lambert, and its revival is supported by five pages of discussion and the description of a new species. It is lamentable to think of the amount of space and energy that have been expended over the unhappy indefiniteness of Pomel's generic diagnosis. It remains to be seen in what way the *Revue critique de Paléozoologie* will deal with this latest outbreak of heterodoxy, and M. Fourtau seems to anticipate severe treatment.

A considerable space is devoted to the *Holectypi*, and a new species, *H. dowsoni*, is described. The North African variety of *H. cenomanensis* receives a name, and is well figured. A new and very fragmentary form of *Archiacia* is described. Although the principle of the foundation of new species on imperfect specimens is usually disastrous, the excessive rarity of complete examples of this genus makes such treatment necessary, if any progress is to be made. A new *Echinobrissus*, and a form referred to *Epiaster* in default of a better resting-place, bring the list to a close, save for the *Hemiasters*. Three species of these are new, and the description of one, *H. toxasteristoma*, is accompanied by a valuable table of measurements.

The four lithographic plates, drawn by F. Gauthier, are clear and adequate, but from many points of view the inclusion of a few more anatomical drawings, as distinct from general views, of the specimens would have been desirable.

H. L. H.

V.—Laccolites of the Bushveld and Karroo, South Africa.—In some "Further Observations on the Origin of the Rand Bankets" (*S. African Journ. Sci.*, viii, p. 357, 1912) Professor E. H. L. Schwarz compares the type of laccolite of the Bushveld, Transvaal, with that of the Karroo. In the Transvaal a great laccolite of red granite occupies the Bushveld to the north of Pretoria. It is 255 miles long from east to west, and on an average 80 miles broad, although in the central portions the breadth is nearly equal to the length. The body of the laccolite rests on the rocks of the Transvaal system, with the Black Reef quartzites below, the Dolomite above, and the highly ferruginous sediments of the Pretoria Series on top. Into these latter have been intruded a vast series of sills or dykes of diabase or altered dolerite. The author regards it as inconceivable that such an immense mass of igneous rock should flow over and rest upon the ferruginous and calcareous rocks without absorbing material from them. The Karroo laccolite, formed of dolerite, occupies an area about 700 miles long by 200 broad, while the individual sills are from 100 to 500 feet thick; and Professor Schwarz estimates that the entire material would, if melted up, form a ball 50 miles in diameter. He has no doubt that a considerable amount of sedimentary material has been assimilated. Thus a dyke 100 feet or more thick may have been intruded at a high angle and then bend over to follow the bedding plane of the sediments as a sill. If the dolerite were entirely new material, that had not melted out its cavity, there should be visible above the bend of the dyke to the sill some continuance of the crack through which the dolerite came, but he has seen no evidence of this in the Karroo.

VI.—Geological Survey of the Transvaal.—Memoir No. 6, issued by the Mines Department, Pretoria, 1912, is entitled *The Geology of the Murchison Range and District*; it is by Mr. A. L. Hall, B.A., F.G.S., and is accompanied by a geological map on the scale of about 1 inch to $2\frac{1}{3}$ miles. The Murchison Range, which attains an elevation of 2,980 feet, is formed mainly of the Moodies' Series, consisting of quartzites, phyllites, slates, and conglomerates, with ironstones and limestones; and this series presents characters that suggest correlation with the Swaziland system. The Black Reef and succeeding Dolomite Series of the Transvaal system, rest unconformably on the Moodies' Series. The granite of the Low Country is intrusive into the older rocks of the Murchison range, and occupies as regards age a position between those rocks and the Transvaal system. Economically the Black Reef Series and the older Schist belts of the Murchison range are of importance as gold-bearing rocks; there are likewise extensive tracts of mica, some of which occur in coarse white granite pegmatites that are intrusive into the older granite, while others are associated with the newer Palabora granite. Deposits of corundum also occur, but at present it is not possible to estimate the quantity available. More prospecting is required in reference to all the mineral deposits, but the author regards the district as specially suited for small mining enterprises. He further observes that there are remarkably fertile stretches of country with permanent and abundant water and a healthy climate, admirably adapted for agricultural operations.

VII.—Geological Survey of New Zealand.—A quarto volume on *The Geology of the Dun Mountain Subdivison Nelson*, by Messrs. J. M. Bell, E. de C. Clarke, and P. Marshall, forms the subject of an official Bulletin (No. 12, New Series, Wellington, 1911). The area here described lies in the northern part of the southern island of New Zealand, bordering Tasman Bay. The eastern portion, occupied by forest-covered mountains, rises to more than 3,000 feet above sea-level; the western part, drained by the River Waimea and its tributaries is fertile and highly cultivated lowland. The geological formations are grouped as follows:—

Recent		Alluvial deposits, Travertine, etc.
Miocene . .	Moutere Gravels	River Gravels.
	Jenkins Hill Series	Conglomerates, sandstones, shales, mudstones, limestones, and occasional coal-seams.
Late Mesozoic or Early Cainozoic	Intrusive rocks of "Mineral Belt"	Ultra-basic rocks which pierce the Matai Series.
Trias-Jura . .	Matai Series . .	Conglomerates, breccias, grauwackes, limestones, and argillites, with contemporaneous volcanic rocks.

Among the fossils of the Matai Series are species of *Spirigera*, *Monotis*, *Halobia*, *Trigonia*, and *Gryphæa*. The main object of the work is to describe the nature and extent of the copper-deposits which occur in the Mineral Belt. The associated rocks include peridotites, serpentine, etc., and of these petrological accounts are given. Other economic products of the district are gold, chromite, coal, and building materials.

VIII.—Cambridge County Geographies.—We have received the volume on North Lancashire by Dr. J. E. Marr (Cambridge, at the University Press, 1912, price 1*s*. 6*d*.). It contains a capital account of the physical features, with brief references to the geological structure. The mountains; the fells, some of which are rocky and step-like, while others are peat-covered moorlands; the watersheds and passes, the bare and fissured limestone-tracks known as 'clints', the lakes, tarns, and rivers are duly if briefly described. There appear to be no great forests, but much coppice, and charcoal-burning is carried on for the manufacture of gunpowder. The iron-ore, building-stone, the slate of Tilberthwaite, and rock-salt are among the industries of geological interest. Many good views of scenery are given, and there is a portrait of Sir Richard Owen, who, as a Lancashire man, is rightly given a place with Whewell and Sir Edward Frankland in the section entitled 'Roll of Honour'.

IX.—Brief Notices.

1. Geology of Wyoming.—A memoir on the *Geology and Mineral Resources of a Portion of Fremont County, Wyo.*, has been written by the State Geologist, Mr. C. E. Jamison (Bulletin No. 2, series B, 1911). An account is given of the various geological formations from Pre-Cambrian to Tertiary (Eocene), of their structure and history, with preliminary descriptions of the physical features, climate, and agriculture. The chief mineral products are oil, gold, building-stones, and gypsum.

2. Western Australia.—We have received vol. i, pt. ii, 1912, of the *Records of the Western Australian Museum and Art Gallery*, edited by the Director, Mr. Bernard H. Woodward, F.G.S. In this work Mr. L. Glauert continues an account of the mammalian remains from the Mammoth Cave, describes some "Fossil Marsupial Remains

from Balladonia" and "Permo-Carboniferous Fossils from Byro Station, Murchison District".

3. Molybdenum Ores of Canada.—Dr. T. L. Walker has prepared a "Report on the Molybdenum Ores of Canada" (Dep. Mines, Ottawa, 1911). The ore most widely distributed is Molybdenite: there also occur Molybdite and Wulfenite (molybdate of lead). All information relating to the subject has been gathered, and the author has personally examined many of the Molybdenum deposits.

4. Seismology.—We have received several numbers of the *Bulletin of the Seismological Society of America*, commenced in 1911, under the direction of Messrs. J. C. Branner, A. C. Lawson, and S. D. Townley. While dealing particularly with phenomena observed in America, notices are included of earthquakes in other parts of the world. In No. 4 (December, 1911), Mr. Lawson described some Post-Glacial faults; Mr. J. S. Diller contributes a memoir with portrait of Major Clarence E. Dutton; and there are various articles relating especially to earthquakes, earthquake epicenters, seismographs, etc.

5. Megascopic Pseudostromatism.—Mr. S. Rennie Haselhurst (Univ. Durham Phil. Soc., iv, p. 162, 1912) introduces the term mentioned in describing the larger forms of structure produced by overfolding and thrusting, shearing and cleavage, as developed in shales and micaceous sandstones in the Coal-measures of Northumberland. The characters, which simulate fluxion-structure, appear to be similar to those described by Dr. A. Strahan in the violently disturbed Coal-measures on the Pembrokeshire coast (see *Summary of Progress Geol. Survey for 1905*, p. 60).

6. *Arctotherium* from Yukon.—A new species of this giant bear, named *Arctotherium yukonense*, has been described by Mr. Lawrence M. Lambe (*Ottawa Nat.*, xxv, p. 21, 1911). The specimen, a well-preserved skull, was found at a depth of 40 feet in frozen Pleistocene deposits at Gold-run Creek, Yukon, and the discovery extends the known range of this mammal very far to the north of any previous record. The genus is regarded as intermediate between the old-world *Hyænarctos* and *Ursus*.

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 19, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Geology and Palæontology of the Warwickshire Coalfield." By Robert Douglass Vernon, B.A., B.Sc., F.G.S.

The main objects of this paper are to determine the true age of the so-called 'Permian' rocks of Warwickshire, and their stratigraphical relationship to the underlying Carboniferous rocks and to the overlying deposits of Triassic age. Further, the Carboniferous rocks are subdivided into groups, and the age of the subdivisions is determined from a study of the fossil flora. The results may be summarized as follows:—

TABLE ILLUSTRATING THE CARBONIFEROUS AND PERMIAN SUCCESSION IN WARWICKSHIRE.

Name.	*Characters.*	*Chief Fossils.*	*Thickness in feet.*
PERMIAN.	Calcareous, false-bedded red sandstones, and lenticular red marls spotted with green; with two horizons of Limestone Conglomerates, the lowest of which forms the base.	*Walchia filiciformis* (Schlotheim) *Calamites* sp. *Dasyceps bucklandi* (Lloyd). *Oxyodon britannicus*, von Huene	? 1,000
KEELE BEDS.	Red and purple sandstones and marls, with marly breccias, and, towards the base, beds of grey sandstone. Three thin beds of *Spirorbis* Limestone, the lowest (and thickest) of which is taken as the base.	*Pecopteris polymorpha*, Brongn. *P. arborescens*, Schloth. *P. miltoni* (Artis). *Spirorbis.* Ostracoda.	1,000 to 1,500
HAUNCHWOOD SANDSTONES.	Grey sandstones and shales, with thin coals and some red mottled marls towards the top.	*Neuropteris ovata*, Hoffmann. *N. scheuchzeri*, Hoffmann. *N. rarinervis*, Bunb. *Pecopteris miltoni* (Artis). *P. arborescens*, Schloth. *Sphenophyllum emarginatum*, Brongn.	300 to 450
NUNEATON CLAYS.	Red and purple mottled marls and clays, with thin Espley Rocks, a *Spirorbis* Limestone, and local breccias.	*Cordaites borassifolius*, Sternb. *Calamites* sp. *Spirorbis.* Ostracoda. Fish-remains, undetermined.	80 to 150
MIDDLE COAL-MEASURES.	Grey sandstones and shales, with thick coal-seams and beds of Ironstone Sandstones and breccias towards the top, which thicken to the north. An impersistent conglomerate forms the base.	*Zeilleria delicatula* (Sternb.). *Corynepteris coralloides*, Gutbier *Sigillaria boblayi*, Brongn. *Lingula mytiloides* (Sow.). *Myalina compressa*, Hind. *Pterinopecten papyraceus* (Sow.). *Carbonicola aquilina*, Sow. *Anthracomya williamsoni*, Brown *Naiadites carinata*, Sow. *Megalichthys hibberti*, Agassiz. *Rhizodopsis sauroides*, Willm. *Acanthodes wardi*, Egert.	400 in the south to 700 in the north.

On stratigraphical and palæontological evidence it is shown that a large area of rocks previously mapped as Permian is really Carboniferous.

The Carboniferous rocks are subdivided into groups which, on palæobotanical evidence, are proved to belong to the following three horizons of the Westphalian Series: the Upper Coal-measures, the Transition Measures, and the Middle Coal-measures; the Lower Coal-measures are found to be absent.

The fossil flora is described in detail, and a brief account is given of the freshwater and marine faunas of the Middle Coal-measures. The Carboniferous rocks of Warwickshire are correlated with those of the other coal-fields of the Midland province, and it can thus be demonstrated that there is a marked southerly attenuation and overlap of each of the subdivisions of the Carboniferous System.

Some account of the Permian and Trias is given, in order to show the unconformable relationship of the Permian to the Carboniferous on the one hand, and that of the Trias to the whole of the Palæozoic rocks of the district on the other.

2. "On the Discovery of a Fossil-bearing Horizon in the Permian Rocks of Hamstead, near Birmingham." By Walter Henry Hardaker, M.Sc. (Communicated by Professor Charles Lapworth, LL.D., F.R.S., F.G.S.)

Some quarries in the Permian rocks in the neighbourhood of Hamstead, near Birmingham, have afforded to the author an interesting series of fossils. These consist chiefly of the impressions of plants, and of the footprints of amphibia assignable to several species.

The quarries from which the fossils have been obtained occur in that broad band of strata which is coloured upon the Geological Survey map as Permian, and fringes the eastern side of the South Staffordshire Coal-field.

The author describes and illustrates in detail the group (and sub-groups) in which the fossil occur, and shows that the group as a whole belongs in its lower part to the Midland Middle Permian (or Calcareous Conglomerate and Sandstone) Division of Mr. Wickham King, and in its upper part to his Upper Permian (or Breccia and Sandstone) Division.

Most of the plants and animal footprints discovered belong apparently to recognizable forms which have been long known to occur in the Rothliegende (or typical Lower Permian) of Germany, and they have little or no resemblance to those of the undisputed Upper Carboniferous of any known area; and the conclusion is drawn that these fossil-bearing Hamstead strata must in future be regarded as of Rothliegende or true Lower Permian age.

On Wednesday, June 26, 1912, a Conversazione, at which about four hundred ladies and gentlemen were present, was held in the Society's Apartments, from 9 to 11.30 p.m. In the course of the evening, two lectures, illustrated by lantern-slides, were given; one on "Tin-Mining in the Federated Malay States", by J. B. Scrivenor, M.A., F.G.S., and the other on "Palæolithic Paintings in the Caverns of Northern Spain", by Dr. A. S. Woodward, F.R.S., Sec.G.S. Many interesting exhibits were shown by various Fellows of the Society.

The next meeting of the Society will be held on Wednesday, November 6, 1912.

MISCELLANEOUS.

The Royal Society.—The Royal Society began the commemoration of its 250th Anniversary, under the presidency of Sir Archibald Geikie, K.C.B., by an evening reception of Delegates and Fellows, on July 15, at Burlington House. On the special anniversary, July 16, there was a good attendance at a short commemorative service at Westminster Abbey, when the Dean, the Right Rev. H. E. Ryle (late Bishop of Winchester), delivered an appropriate discourse. Subsequently there was a formal reception of the Delegates at Burlington House; while in the evening a banquet in the Guildhall was attended by nearly 500 distinguished visitors and Fellows, including the two Archbishops, Cardinal Bourne, the Prime Minister, the Lord Chief Justice, and several Ambassadors. The toast of the Royal Society was proposed by Mr. Asquith, who remarked that the Society "is to-day the most vital, if not the most characteristic, monument of King Charles II"; while Lord Morley, who proposed the toast of the "Universities at Home and Abroad", referred to "the desire to spread the light in a way which would be useful for the social life of the communities and the strength of the cities". Later proceedings, on July 17, comprised visits to places of interest in London, a garden party given by the Duke and Duchess of Northumberland at Syon House, and a conversazione in the rooms of the Society. The celebration terminated on the 18th, when the President and Council of the Society and the Delegates were received by their Majesties the King and Queen at Windsor Castle, and all the Fellows of the Society (with wife or daughter) were invited to an afternoon party in the Castle grounds. The more permanent mementoes of the celebration are the publication (1) of *The Signatures in the First Journal-book and the Charter-book of the Royal Society*, being a facsimile of the signatures of the Founders, Patrons, and Fellows from the year 1660 to the present time—a veritable édition de luxe, issued in imperial quarto; and (2) of a third edition of *The Record of the Royal Society*, a handsome volume in crown quarto (pp. 483). This work has been edited by the President, who has rewritten the first chapter which contains a narrative of the Foundation and Early History of the Society. The Chronological Register and Alphabetical List of Fellows has been revised, and now includes all names from the year 1663 to May, 1912. There are views of old Gresham College, and of the residences of the Royal Society in Crane Court and Burlington House. The portraits are of King Charles II, Robert Boyle, Sir Christopher Wren, John Evelyn, Sir Isaac Newton, Sir Hans Sloane, Benjamin Franklin, Thomas Young, Sir Humphry Davy, John Dalton, Michael Faraday, Lord Kelvin, Lord Lister, and Charles Darwin. The earlier editions of the Record contain other portraits and illustrations of medals not here reproduced.

International Geological Congress.

The twelfth session of the Congress is to be held in Toronto, Canada, and will continue for eight days, beginning on or about

August 21, 1913. H.R.H. the Duke of Connaught, Governor-General of the Dominion, has consented to become Honorary President. Fuller particulars relating to arrangements will be issued later. Meanwhile the Executive Committee, with Professor F. D. Adams, F.R.S., as President, have been making arrangements for a series of excursions before, during, and after the meeting of the Congress. These will be planned so as to afford an insight into the geology and physiography of Canada, including the mineral and other natural resources of all the more accessible portions of the country.

The following topics have been selected by the Executive Committee as the principal subjects for discussion at the Congress:—

1. The coal resources of the world.
2. Differentiation in igneous magmas.
3. The influence of depth on the character of metalliferous deposits.
4. The origin and extent of the pre-Cambrian sedimentaries.
5. The sub-divisions, correlation, and terminology of the pre-Cambrian.
6. To what extent was the Ice Age broken by interglacial periods?
7. The physical and faunal characteristics of the Palæozoic seas with reference to the value of the recurrence of seas in establishing geologic systems.

Correspondence should be addressed to the Secretary, International Geological Congress, Victoria Memorial Museum, Ottawa, Canada.

The Stuttgart Mammoth.—There has just been mounted by Dr. Eberhard Fraas for exhibition in the Royal Natural History Museum, Stuttgart, a specimen which may certainly be regarded as the largest nearly complete mammoth skeleton yet discovered.

In August, 1910, there were found at Steinheim, in the diluvial deposits of the River Murr, a tributary of the Neckar, in Swabia, a number of fossil bones indicating the remains of an unusually large mammoth. As a proof of its size it may be noted that the skull weighs nearly three-quarters of a ton, and the height of the skeleton is over 13 feet.

The specimen is remarkable for the abnormal length of the legs; probably it was a swift-moving animal; and for a degree of general lightness of frame, indicating activity. The tusks are well shaped with a slight semicircular curve, but are much less in size than the normal type, being only $7\frac{1}{2}$ feet in length, whereas many of the Siberian and American specimens have tusks double that size. These features lead naturalists to regard it as belonging to a late type of mammoth when the transition to the smaller and more active elephants was commencing.

It is so fine a specimen that it is to be hoped that casts of at least the most important portions of the skeleton may be obtained for our Natural History Museum in London.

We regret to record the sudden death of the Rev. Robert Ashington Bullen, B.A. (Lond.), F.L.S., F.G.S., F.Z.S., F.R.A.I., Memb. Malac. Soc., of Hilden Manor, Tonbridge, Kent, when crossing to Germany by the Calais night mail boat on August 14. He was interred at Brookwood on August 20. We hope to publish an account of his work next month.

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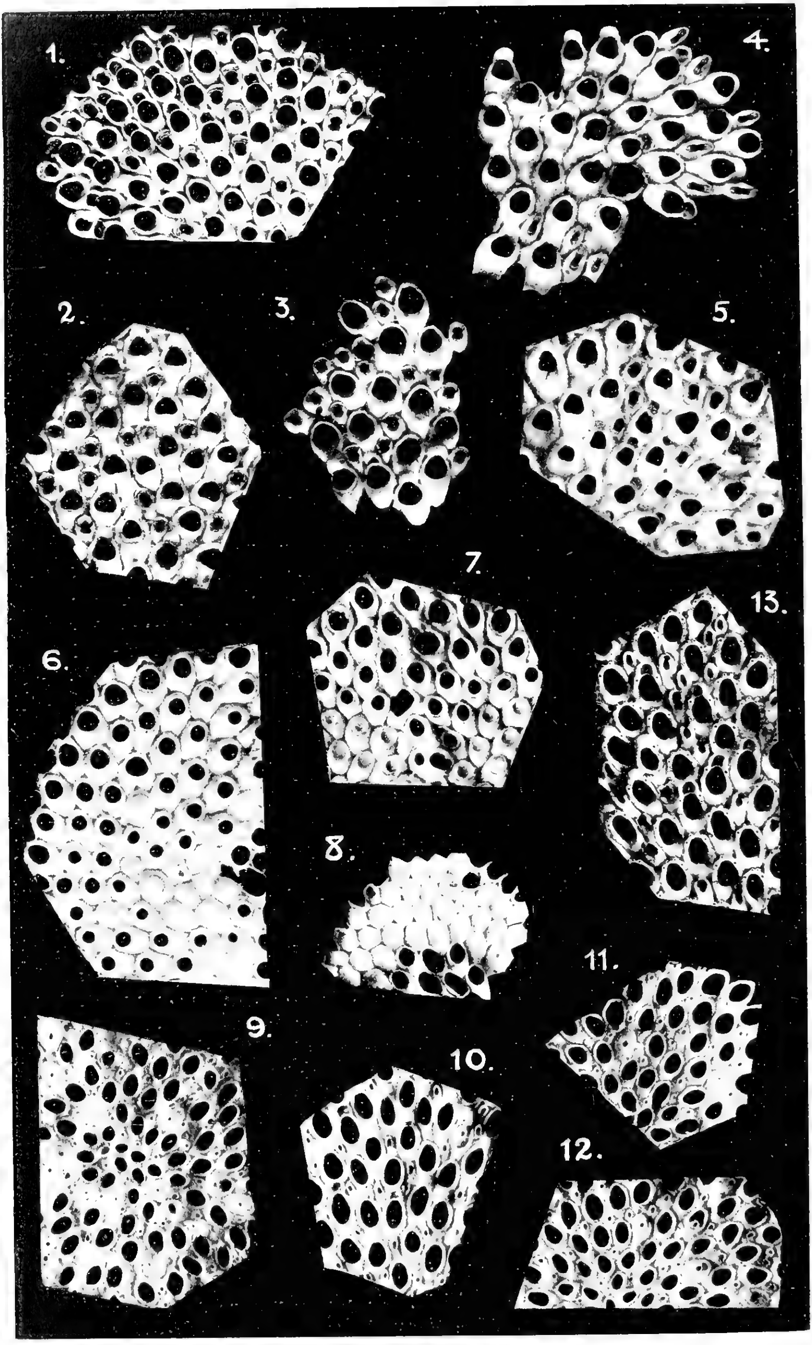

R. M. Brydone, Photo. Bemrose, Collo.

Chalk Polyzoa.

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ORIGINAL ARTICLES.

I.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from the July Number, p. 296.*)

(PLATE XXII.)

Membranipora pyrigera, sp. nov. (Pl. XXII, Figs. 1–5.)

Zoarium always adherent, rarely large.

Zoœcia pyriform when not crowded, small, the earlier forms larger than the later, but individually very variable; area sub-triangular; a slight internal front wall, occasionally surrounded by a faint line; under the oœcia the rim is very thin, very low, and set distinctly back from the general curve.

Oœcia small, globose and prominent, the free edge coinciding very nearly but not quite accurately with the general curve of the margin of the area.

Avicularia short and pyriform, with a narrow oval aperture in the upper part deep-set within a short wide pyriform area, the sides of which near its lower end are folded over and inwards into hour-glass shape to a point which slightly overhangs the aperture; the rounded upper end of the area is also bent upwards and inwards into a hood shaped like a flat meniscus.

This species is one of the group of which *M. confluens*, Rss., is the best known. It seems to be easily distinguishable by its avicularia from any other described species. It is of regular occurrence throughout the zone of *A. quadratus* and in the lower part of the zone of *B. mucronata*; and the form of the zone of *M. cor-anguinum* illustrated by Fig. 4, and the form of the zone of *Marsupites* illustrated by Fig. 5, are probably stages in its development.

Membranipora tenebrosa, sp. nov. (Pl. XXII, Figs. 6–8.)

Zoarium always adherent; all my specimens are quite small.

Zoœcia very variable in size, more or less hexagonal, with a slight tendency towards being sub-pyriform; the area occupies the upper half and is circular or nearly so, and lies at the bottom of a slight circular depression, the rim of which is often marked by a faint line; a number of the zoœcia, varying according to the state of preservation and the care taken in cleaning, have smooth imperforate lids fitted to the rims of these depressions, often so closely that no suture can be detected, and the zoœcium appears to have a perfectly smooth and unbroken surface; the lids are generally convex, but are sometimes irregularly concave.

Oœcia helmet-shaped and small, rarely present, and when present fragile; the specimen with oœcia from which Fig. 7 is taken is quite exceptional.

Avicularia. None observed.

The circular area restricted to the upper half of the zoœcium distinguishes this species from any other of the lidded species yet described. It occurs sparingly in the zone of *A. quadratus*, the only zone from which I appear to have it.

MEMBRANIPORA PELLICULA, sp. nov. (Pl. XXII, Figs. 9–12.)

Zoarium always adherent, and so slightly raised as to be easily mistaken by the naked eye for a skin of dirt or chalk.

Zoœcia sub-pyriform to pyriform when not interfered with by other zoœcia, but often in crowded spots losing all trace of pyriformity and very variable in size; the area occupies normally about two-thirds of the length of the zoœcium and is a long narrow ellipse; it is often closed by a slightly convex lid in which there is a small elliptical pore of variable position.

Oœcia helmet-shaped, unusually long and distinctly squarish at the upper end.

Avicularia very numerous and very small, being narrow pyriform bodies with a smooth convex surface having a very narrow slit in its upper half, which is rather abruptly elevated above its lower half.

The extreme shallowness of the zoarium, the perforated lids, and the small and abundant avicularia form a combination which readily distinguishes this species from any other. It does not appear to occur below the subzone of *O. pilula*, in which it is very rare; but in the subzone of *A. quadratus* and the lower part of the zone of *B. mucronata* it occurs freely.

MEMBRANIPORA WITHERSI, sp. nov. (Pl. XXII, Fig. 13.)

Zoarium always adherent.

Zoœcia faintly sub-pyriform, and having a slight internal front wall, and tilted considerably, the head being much higher than the foot; the area is a straightish-sided ellipse about ·3 mm. long by ·2 mm. wide; on the zoœcial wall at the extreme head there is a pair of tiny projecting tubes; a little below them there is a pair of stout perforated spine bases with an imperforate pair some way below them; beneath the oœcia the zoœcial wall is very thin.

Oœcia widely helmet-shaped, distinctly large in proportion.

Avicularia of two kinds—one simple small pyriform bodies like those of *M. pellicula*, but having a much wider aperture, and tilted like the zoœcia; the other similar, but larger bodies lying horizontal and having also a terminal aperture formed by the upper end being sliced off by a downward and after a short way outward curving transverse cut along a line which falls just within the upper end of the horizontal aperture, so that the two apertures are just continuous.

At present I only know this species from the subzone of *A. quadratus*, in which it is not uncommon.

These four species illustrate well the gentle transition between normal *Membraniporæ* and the group which is generally assigned to

Pyripora and for which Canu[1] has proposed the genus *Pyriporella*. For my own part I find it so very difficult to draw any line between the two that I do not think it safe to treat them as generically distinct in the Chalk.

EXPLANATION OF PLATE XXII.

(All figures × 12 diams.)

Fig. 1.	*Membranipora pyrigera.*	Subzone of *A. quadratus* (I. of W.).
,, 2.	,,	,, ,, Portsdown, Hants.
,, 3.	,,	,, *O. pilula*, West Meon, Hants.
,, 4.	,,	Zone of *M. cor-anguinum*, Gravesend.
,, 5.	,,	,, *Marsupites*, West Tisted, Hants.
,, 6.	*Membranipora tenebrosa.*	Subzone of *A. quadratus*, Shawford, Hants.
,, 7.	,,	,, *E. scutatus*, var. *depressus*, Newhaven.
,, 8.	,,	,, ,, Ropley, Hants.
,, 9.	*Membranipora pellicula.*	,, *A. quadratus*, Portsdown, Hants.
,, 10.	,,	,, ,, Hensting, Hants.
,, 11.	,,	,, ,, Portsdown, Hants.
,, 12.	,,	,, ,, Hensting, Hants.
,, 13.	*Membranipora Withersi.*	,, ,, Hensting, Hants.

II.—Carboniferous Zones Illustrated by Corals: an Exhibit at the Natural History Museum.

By W. D. Lang, M.A., F.G.S.

In view of the attention lately devoted by geological workers to the British Lower Carboniferous rocks and their fossils, an exhibit has been arranged in the Department of Geology at the Natural History Museum to illustrate the occurrence in the field of Corals in reference to the division of the Lower Carboniferous rocks into zones.

As is well known, Dr. A. Vaughan,[2] the pioneer of modern Lower Carboniferous stratigraphy, divided these rocks into five groups or zones, each named after the genus of Coral or Brachiopod dominant during the time that the zone bearing its name was deposited. A zone is thus seen to be all the material deposited during a given time. The time during which a zone was deposited has been termed by Buckman a 'hemera',[3] a term which has not come into common use, probably because it is as easy and more natural to say, for instance, 'in *Caninia* time' than 'in the hemera of *Caninia*'. It is true that the former might mean 'during the whole period during which *Caninia* existed', while 'hemera', as defined, is used for the time during which an organism was dominant; but in practice such confusion rarely occurs, and, until it is felt, the term 'hemera' is not likely to be generally used. Vaughan further divided his Carboniferous

[1] *Iconographie des Bry. Foss. de l'Argentine*, pt. ii, p. 234.

[2] Vaughan, "Palæontological Sequence in the Carboniferous Limestone of the Bristol Area": Quart. Journ. Geol. Soc., vol. lxi, pp. 181–307, 1905.

[3] Buckman, "The Bajocian of the Sherborne District," Quart. Journ. Geol. Soc., vol. xlix, p. 481, 1893. For a further explanation of the term, see the lucid and amusing article by Buckman, "The term Hemera," Geol. Mag., Dec. IV, Vol. IX, pp. 554–7, 1902, followed by correspondence in Geol. Mag., Dec. IV, Vol. X, 1903. The zone also is discussed in these papers.

zones into sub-zones named after species of Corals, Brachiopods, and, in one instance, a Lamellibranch Mollusc.

Now all Vaughan's zones except two are named after Coral genera; and for these dissenting zones there are corresponding Coral equivalents, since the hemera of *Lithostrotion* nearly coincided with that of the Brachiopod *Seminula*, and the hemera of the Coral *Caninia* with that of *Syringothyris*. Again, the only sub-zones named after Corals are the two subdivisions of the topmost zone. It is possible, then, with the Corals used by Vaughan as the indices of his zones and sub-zones to make six consecutive divisions of the Lower Carboniferous rocks. The main part of the exhibit demonstrates these six subdivisions, namely, from below upwards, the zones of *Cleistopora*, *Zaphrentis*, *Caninia*, *Lithostrotion*, and the sub-zones of *Dibunophyllum* θ and *Lonsdalia floriformis* of the *Dibunophyllum* zone, each with its distinctive letter for abbreviated reference, K, Z, C, S, D_1, and D_2; and gives examples of the Corals after which the zones are named, with, in some instances, another species found with the zonal Coral, and diagrams showing the zonal Corals' structure.

Since it was in the gorge of the River Avon at Bristol that Vaughan founded these subdivisions of Lower Carboniferous rocks, photographs of this typical section have been placed at the sides of the case, and alongside them diagrams showing the limits of the zones traversed as the right bank of the Avon is followed from north to south.[1]

It is to be expected in most cases where stratigraphical divisions are founded upon a single dominant species or genus that it will be possible to apply the same divisions to other areas with a strictness that is only inversely proportional to the distance traversed. Thus Vaughan's zones, though found to hold good in the main, require some modification where the Lower Carboniferous rocks of other areas in the British Isles have been examined.[2] It is not at present possible to show these modifications, and this exhibit is confined to the zones of the typical area which has served as a basis for subsequent work.

Two other points need emphasis in connexion with Vaughan's zones. The difference between the time during which a species existed and its hemera has already been noted. Again, the sequence of zones does not necessarily imply a phylogenetic series.[3] Thus, while *Caninia* is almost certainly a direct derivative of *Zaphrentis*, it probably does not lead on to *Dibunophyllum*; and *Cleistopora*, even if a Coral, is certainly not a radical of the Rugose genera of the higher zones. It is thought that there was much migration of Coral

[1] Professor S. H. Reynolds kindly lent his negatives of the photographs published in Vaughan's paper, "The Carboniferous Limestone Series (Avonian) of the Avon Gorge," Proc. Brist. Nat. Soc., ser. IV, vol. i, pt. ii, pp. 74–168, 1906, from which the exhibited photographs were printed.

[2] e.g. in North-West Ireland, see "The Lower Carboniferous Succession at Bundoran in South Donegal" in *The Geology of Parts of North-Western Ireland*, issued by the Geologists' Association for the August excursion, 1912, p. 9.

[3] See Carruthers, "On Coral Zones in the Carboniferous Limestone": Geol. Mag., Dec. V, Vol. VII, p. 172, 1910.

stocks[1] from area to area, and thus in a given district one stock supplanted another, causing either its extinction or its migration elsewhere.

Vaughan's work, starting with frankly stratigraphic aims, has given stimulus to purely palæontological work which promises to revolutionize the present knowledge of Palæozoic Corals. Though good work has been already done, notably by Carruthers,[2] the field is too vast for generalizations yet to have been established. But a few points in fossil Coral work seem to become increasingly clear. (1) The lack of knowledge as to what characters are directly the result of environment and what directly due to heredity. (2) Our ignorance of the bionomic significance of Coral skeletal structures. (3) The independent acquisition of similar structures in Corals of presumably different ancestry (e.g. the 'central area' of various unrelated genera formerly grouped as Clisiophyllids). (4) The importance of the earliest stages of the Coral skeleton. From these follow (5) the futility of a description and figure of a simple Coral giving a transverse section at one level only; serial sections (the more the better) are absolutely necessary for descriptive purposes; and (6) the necessity of the means of cutting any required number of serial sections in studying any species.

The above results may be thought discouraging, and our ignorance under the old, if artificial, classification, bliss. But advances in knowledge are bound to be superficially destructive, and already some constructive work has been done. It is hoped that some results will shortly be shown in the remaining side of the zonal exhibit case. Meanwhile laborious work alone can wrest from the Corals the story of their evolution.

III.—The Uppermost Silurian and Old Red Sandstone of South Staffordshire.

By W. Wickham King, F.G.S., and W. J. Lewis, B.Sc.

In the core of the Netherton Anticline at Saltwells, near Dudley, in the vicinity of a small area of basalt marked on the Geological Survey maps, Mr. King, in February last, discovered a series of rocks, ranging from the Upper Ludlow Mudstones to the Old Red Sandstone, cropping out from beneath the base of the Coal-measures of South Staffordshire. During April Mr. Lewis independently recognized Silurian here, and we agreed to work out the details together.

[1] e.g. the case recorded in "The Lower Carboniferous Succession at Bundoran in South Donegal" in *The Geology of Parts of North-Western Ireland*, issued by the Geologists' Association for the August excursion, 1912, p. 14.

[2] Carruthers, "The Primary Septal Plan of the Rugosa," Ann. Mag. Nat. Hist., ser. VII, vol. xviii, pp. 356–63, 1906; "A Revision of some Carboniferous Corals," Geol. Mag., Dec. V, Vol. V, pp. 20, 63, and 158, 1908; "The Evolution of *Zaphrentis delanouei* in Lower Carboniferous Times," Quart. Journ. Geol. Soc., vol. lxvi, pp. 523–38, 1910. Of other authors' publications, the most important is that by Salée, "Le Genre *Caninia*," Mémoire couronné au Concours interuniversitaire des Sciences minérales de 1910, publié sous les auspices du Ministère des Sciences et des Arts, Bruxelles, 1910.

Mr. J. Beete Jukes, in 1859, thought that the Old Red Sandstone, Carboniferous Limestone, and Millstone Grit were not laid down in South Staffordshire.[1] It is, however, within the knowledge of one of us that he was afterwards shown, in 1866 or 1867, some rocks like Old Red Sandstone, and a limestone containing *Pterygotus* and *Lingula cornea* (?), found beneath the Coal-measures of South Staffordshire, at the bottom of the Wassell Grove Pits, Hagley, 3 miles south of Saltwells.[2] Afterwards at the Manor Pit,

FIG. 1. Map of area referred to in this paper. Scale = 3 miles to 1 inch.

[1] *South Staffs. Coal-field*, 2nd ed., pp. xii, 134 (Mem. Geol. Surv.). Since then Carboniferous Limestone and Millstone Grit have been found underground at the northern end of the coal-field (Q.J.G.S., vol. lxii, p. 523, 1906, and Trans. of North Staffs. Club, 1903–4, p. 123; cf. Q.J.G.S., vol. lv, pp. 126–7, 1899.

[2] *Dudley Guardian* of June 22, 1867. Mr. King has found on this pit mound pieces of the Temeside Bone-bed with *L. cornea*, *Onchus*, and Eurypteridæ, green shales covered with black markings of Eurypteridæ, and red and purple micaceous sandstones.

Halesowen, 4 miles south-east of Saltwells, the Ledbury Passage or Temeside Beds were pierced, containing *Lingula cornea* and *Cephalaspis Murchisoni*, etc.[1] Mr. Jukes[2] had, however, already recorded red beds at the Level Colliery[3] and at the Leys Colliery, Brierley Hill, at 290 and 120 feet below the Thick Coal, and Salt Water at Corbyns Hall, and Shut End, Kingswinford, at 172 and 111 feet below the Thick Coal. He pointed out the possibility of Old Red Sandstone forming the floor of the coal-field at the Level and Leys Collieries. Kingswinford is 2½ miles to north-west, and the Leys Pits 2 miles west, and the Level Pit only a quarter of a mile west of Saltwells. These localities are shown on Map, Fig. 1. In 1878 Mr. George Jones contented himself with the record that 'Silurian Beds' were exposed at Netherton.[4]

The uppermost Silurian and Lower Old Red Sandstones of Saltwells are exposed in the northern part of the Netherton Anticline in an area, 400 yards or less in width from east to west, and 1 mile long from north to south, commencing close to Brewins Tunnel and ending at a point near to Saltwells Inn. Two miles south of Saltwells Inn the Silurian again emerges at the Hayes, near the Lye, within an area 100 yards from east to west and 300 yards from north to south. The strike of the rocks is in both areas partly S.S.W. to N.N.E. and partly S.S.E. to N.N.W. W.S.W. to E.N.E. faults cross the anticline both at Saltwells and the Hayes. The Aymestry and Upper Ludlow Groups also occur at Sedgley, 4 miles to N.N.W. of, and at Turner's Hill, 3 miles to north-west of Saltwells. The four areas are shown on the Map, Fig. 1.

We have endeavoured to arrange the uppermost Silurian of South Staffordshire in the same way as that at Ludlow, so carefully classified by Miss Elles and Miss Slater.[5] In South Staffordshire we cannot identify some of their zones, and certain fossils reach higher horizons than at Ludlow.

Their main divisions were as follows:—

Temeside Group.	F. Temeside shales with Bone-beds F^b and F^d and grits. E. Downton Castle Sandstones with the *Platyschisma* bed (E^b).
Upper Ludlow Group	D. *Chonetes* flags with Ludlow Bone-bed (D^c). C. *Rhynchonella* flags.
Aymestry Group	B. *Dayia* Shales. A. *Conchidium* limestone.

Description of the Beds.

1. *The Aymestry and Upper Ludlow Groups.*—These, in their entirety, are exposed at the Hayes, dipping 40° east where the main road from Stourbridge to Halesowen passes in a cutting across the Netherton Anticline.

[1] Proc. Birmingham Phil. Soc., vol. v, p. 138. The specimens are at the University Museum, Birmingham.
[2] *South Staffs. Coal-field*, 2nd ed., pp. 81, 82.
[3] Cf. *Silurian System*, 1839, p. 478.
[4] Proc. Dudley Geol. Soc., vol. iv, p. 17, 1878.
[5] Q.J.G.S., vol. lxii, p. 195, 1906.

Sir R. Murchison[1] recorded here the Lower Ludlow, and the best sequence in South Staffordshire of the Upper Ludlow. Neither he nor any other writer has been able to announce the thickness of these beds.

The Lower Ludlow is seen underlying the Aymestry Limestone, on the western side of the anticline, north of the main road, by the side of a wall on the east side of a newly erected house.

The succession is thus:—

		ft.	in.
A.[2]	Aymestry Massive Limestone with *Conchidium Knightii*, *Atrypa reticularis*, *Euomphalus alatus*, *Lituites Ibex*, *Strophomena rhomboidalis* and *ornatella*, *Pentamerus galeatus*, etc. . .	4	6
	Nodular limestones with thin blue partings. *Atrypa reticularis* (common), *Encrinurus punctatus*, *O. lunata*, *R. nucula*. (At Sedgley *Conchidium Knightii* occurs in these nodular limestones.)	7	0
B, C.	Limestones with thin blue partings. *Dayia navicula* and *R. nucula* (abundant), *Chonetes minima*, *O. canaliculata* .	8	0
	Limestones (collectively 28 inches) with yellowish-brown partings. *R. nucula* and *Wilsoni*, *O. lunata*	7	0
D.	Calcareous yellowish-green sandstones with thin limestone bands. The latter aggregate 3 feet and some are nodular. *O. lunata*, *Chonetes striatella* (common), *R. nucula* (common), *R. Wilsoni*	12	0
	Calcareous green sandstones	5	0
	Nodular limestones (collectively 4 feet) and calcareous green sandstones	7	0
	Yellowish-green calcareous sandstones which in the upper layers are full of bones	14	6
D[c].	Ludlow Bone-bed with *R. nucula*, *Onchus*, *Thelodus*, *Bellerophon globatus*, *Lingula Lewisii* (medium species), and bones .		6
	Total thickness of Aymestry and Upper Ludlow Groups . .	65	6

In all D (except D[c]) *Chonetes striatella* and *minima* and *R. nucula* are very common. The section continues without interruption with Downton Sandstones (E[a]), thus:—

	ft.	in.
Greenish-yellow gritty shale. (Fish?) spines and black markings	3	3
Hard yellow sandstones with two partings of 6″ and 16″, *Lingula Lewisii* (medium species), and black markings	10	6
	13	9

A large building covers the ground to the east.

We have checked Mr. King's measurements at the Hayes with the beds A, B, C, and D exposed at Sedgley, which were described as Aymestry and Upper Ludlow by Sir R. Murchison and Mr. Jukes.

In the quarries 400 yards and upwards W.N.W. of the Beacon Tower, Sedgley, the Lower Ludlow is exposed with 40 feet of the Aymestry and Upper Ludlow Groups above it. The highest beds

[1] *Silurian System*, 1839, p. 483.
[2] The letters we use are the same as in Q.J.G.S., vol. lxii, p. 195, 1906.

(14 feet) are Upper Ludlow yellowish-green mudstones (D) with many *Chonetes striatella*. This leaves 26 feet for A, B, and C.

The sequence at the first quarry north of Sedgley Church, which we have compared with the Beacon Hill Quarry, is thus:—

		ft.	in.
A.	Aymestry massive limestone with *Conchidium Knightii* . .	6	6
	Nodular limestones with thin blue partings. *Atrypa reticularis*, *R. nucula* (very common), *R. Wilsoni*, *Pentamerus galeatus*, *Conchidium Knightii* (1 foot above massive limestone), *Strophomena rhomboidalis*, *O. canaliculata*, *Chonetes striatella* and *minima* (rare)	5	0
B, C.	Limestones with thin blue partings. *R. nucula* and *Wilsoni* (very common), *O. canaliculata* and *lunata*, *Orbiculoidea rugata*, *Dayia navicula* (common), *Serpulites longissimus* .	4	6
	Limestones with some blue partings at base and thick brown partings higher up. *Rhynchonella nucula* (very common), *O. canaliculata*, *lunata*, and *elegantula*, *Chonetes striatella*, *Orbiculoidea rugata*, *Dayia navicula*, *Cardiola interrupta*, *Orthonata amygdalina*	4	6
	Limestones and brown calcareous sandstones. *R. nucula*, *Chonetes striatella* and *minima* (all common), *O. canaliculata*, *lunata*, and *elegantula*, *R. Wilsoni*, *Lingula lata*, *Cyclonema coralii*	5	6
D.	Calcareous yellowish-green sandstones with thin 2–3 in. limestone bands. *R. nucula*, *Chonetes striatella* and *minima* (all abundant), *R. Wilsoni*, etc.	9	0
		35	0

In all the Sedgley quarries where the massive limestone occurs we find, if the section continues upwards for 25 feet, that *Chonetes striatella* and *minima* abound and *L. lata* occurs. The Aymestry and Upper Ludlow strata below this *Chonetes* zone, both at the Lye and at Sedgley, are lithologically similar, and are in thickness always under 30 feet.

Though the Ludlow Bone-bed cannot so far be found at Sedgley, yet we detected it 1 mile to the S.S.W. at Turner's Hill in an overgrown quarry at the top of the hill and in the adjacent footpath. Murchison recorded limestones and dirty yellowish sandstones of Ludlow age here.[1] The lowest bed in this upper quarry is a peculiar reddish-brown sandstone (D^b) with *R. nucula* and *Chonetes minima* that at Saltwells is within $5\frac{1}{2}$ feet of the bone-bed. Above this are hard quartzitic and fine yellow sandstones. The fine yellow sandstones are similar to the less calcareous parts of the rocks which at Saltwells are interstratified in the two bone-beds' impure limestones, and at Lye occur just above and below the Ludlow Bone-bed. Both these sandstones contain many *L. Lewisii* (medium species) and the yellow sandstones *Onchus* and *R. nucula* and black markings in abundance. They are succeeded by coarser yellow sandstones, like E^a at Lye, with *L. Lewisii*. Coal-measure clays overlie the latter. We have found in the quarry at the bottom of the hill *Strophomena euglypha*, *rhomboidalis*, *ornatella*, *Atrypa reticularis*, etc., and identify the rocks exposed there as belonging to Zone A,

[1] *Silurian System*, 1839, p. 482.

with Lower Ludlow Shales below. The area is much faulted, hiding part of the Upper Ludlow.

At Saltwells (Fig. 2) less than 20 feet of the Upper Ludlow is exposed north and south of the bridge over Messrs. Doulton's tramway.

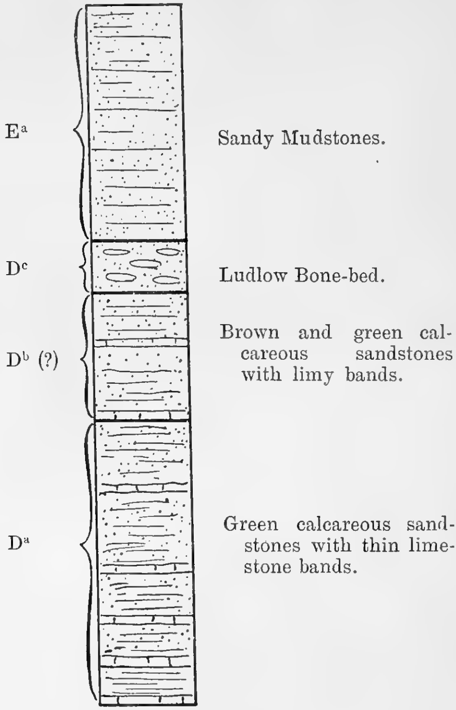

FIG. 2. Section north and south of Tram Bridge, Saltwells.
Scale 8 feet = 1 inch.

The lowest beds (D) are calcareous green sandstones, with thin bands of limestone near the base. They are crowded, especially in the limestone bands, with *Chonetes striatella* and *minima* and—*R. nucula*. *L. lata*, *Holopella obsoleta*, *Orbiculoidea rugata*, *Serpulites longissimus*, *Cornulites serpularis*, etc., also occur.

For $5\frac{1}{2}$ feet below the Ludlow Bone-bed occur shales, calcareous sandstones, and flags, with a more calcareous sandstone at the base, which is lithologically like a zone of D^b at Downton Castle Bridge, namely, a white calcareous sandstone in the centre which weathers to a peculiar and distinctive reddish-brown sandstone, with *Chonetes striatella* and *minima*, *R. nucula* (all very common), *Orthonota semisulcata*, etc.

The Bone-bed (D^c) varies from being 23 inches thick, most of which is an impure limestone, to Bone-bed 4 inches, calcareous sandstone full of black material $9\frac{1}{2}$ inches, Bone-bed $1\frac{1}{2}$ inches.

It contains *Chonetes striatella*, *O. elegantula*, *R. nucula*, *Lingula* sp. (?), fragments of fish scales and bones, *Onchus*, *Thelodus*, *Holopella obsoleta*, *Pachytheca*.

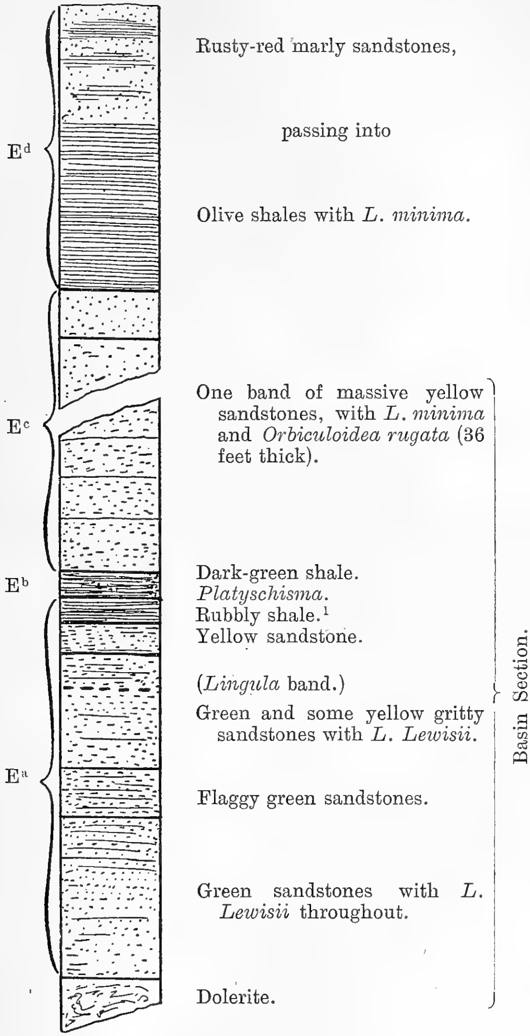

FIG. 3. Section of Downton Sandstones in the lower part of Brewins Tunnel and at the "Basin Section". Scale 8 feet = 1 inch.

[1] This is the lowest bed seen on south side of Brewins Tunnel.

(*To be concluded in our next Number.*)

IV.—On the Discovery of Remains of *Iguanodon mantelli* in the Wealden Beds of Brighstone Bay, Isle of Wight.

By Reginald W. Hooley, F.G.S.

The *Iguanodon*, as is well known, was discovered by Mantell, who in 1825 named it from odd teeth which had a resemblance to the teeth of the recent *Iguana*. Many isolated teeth and bones were subsequently found in the Wealden and Lower Greensand beds to which the names of *I. anglicum* (F. Holl, 1829) and *I. mantelli* (H. von Meyer, 1832) were given. It was not, however, until 1851, when Owen described an associated group of bones on a slab of sandstone from the Kentish Rag (Hythe Beds, Lower Greensand) of Maidstone, Kent, which had been discovered by W. H. Bensted in 1834, that the genus was to any extent known. This specimen has become the type of *I. mantelli*. In 1878 occurred the historic discovery of the skeletons of a number of *Iguanodons* in the Wealden beds of Bernissart, near Mons, Belgium.

Among these, two forms were found, a small and a large. The former was identified as *I. mantelli* and the latter as a new species. These conclusions have been generally accepted by palæontologists, but the question is reopened by the discovery of the specimen now to be described.

Description of the Specimen.—In September, 1899, while searching the cliff about 150 yards west of Cowlease Chine, Isle of Wight, I discovered several pieces of bone in the debris caused by a fall in the cliff. On examining that part of the cliff from which it had been displaced I found many bones in situ. They were lying 8 feet above the *Hypsilophodon* Bed near the base of the 19 feet of blue shales, with *Unio* and *Paludina* in the top and *Cyrena* and *Paludina* at the bottom, as mentioned in the section given in the Geological Survey Memoirs of the Isle of Wight, 1889, p. 15. On carefully removing the shale, a series of eight caudal vertebræ was found lying in connexion and entire, with the exception of two neural spines. In addition there were, anterior to these, and consecutive, two neural and one hæmal spines. The combined length of the neural spine centrum and chevron of the most anterior vertebræ (? the twelfth caudal) was 990 mm., and covered a space 863 mm. wide. On removing the vertebræ and clearing away the matrix I found a fine pubic bone, perfect except the post-acetabular process, which had been broken off in the fall of the mass. Amongst the debris many portions of bone more or less fragmentary were obtained. Many of these I have been able to put together, the result being the centra of four caudal vertebræ, five neurapophyses and two hæmapophyses of caudal vertebræ, the left ilium minus the pre-post-acetabular processes, portions of the right ilium and pubic bones, the sacrum, two lumbar vertebræ, and the posterior moiety of a third.

Portions of the neural spines of the last four sacral vertebræ were preserved. The penultimate and ultimate transverse processes of the right side are intact, and the bases of the remaining three. On the left side there is the full series of five, nearly perfect. This section of the cliff was watched at brief intervals, and from a small slip at the same spot a left femur was obtained.

The bone was broken in its fall. The upper and median trochanter and the posterior moiety of the inner condyle were destroyed. The distal end had been much damaged while in a soft condition, the outer condyle being completely doubled back and the preserved portion of the inner condyle twisted round some distance anterior to its true position. Later, from the same place were obtained the right and left ischium. The former is perfect, but the latter has lost about 10 mm. of the anterior acetabular portion, the obturator process is bent out of position, and the shaft of the bone has been broken, slightly twisted (not the natural twist) and cemented in that position.

The caudal vertebræ found in situ were lying at right angles to the face of the cliff, the posterior being innermost. Although many rolled and odd bones and teeth have been found, the present is the largest number of associated remains of *Iguanodon* yet found in the Isle of Wight.

The Sacrum.—The sacrum possesses five vertebræ. The centra of two anterior vertebræ are anchylosed to these, but the neural spines and arches are lost. These two centra exhibit on the right side wing-like processes placed vertically. The transverse sacral ribs spring from the neural arches as bars of bone, and continue thus to their extremities. The three posterior are fused throughout their length to a plate of bone. This plate between the second and third ribs passes inwards and unites with the centrum beneath the first sacral rib. This rib and the second, for the greater part of their length, are free from the plate and rise well above it. The exterior lateral border of the plate forms a deep upright wall. On a ventral view, this plate is roughly shield-shaped, and the width across the shoulder, which is situated under the third rib, nearly equals the length of its sides. These sides have a slightly concave outline. The posterior border is straight.

There are four sacral foramina.

The Ilium.—The form of that portion of the ilium preserved is close to that figured by Professor L. Dollo,[1] and as the other bones are identical, there cannot be any doubt that the forms of the missing pre-post-acetabular extremities were similar.

The Pubic Bone.—The pubic bone is a remarkably thin plate, the width at the anterior end being one-seventeenth of the depth. It is moderately thick near the acetabular margin, but considerably increases superiorly for union with the ilium. The anterior third of the bone is expanded into a broad circular plate, which is more than half as deep as in the median region of the shaft. This disc-like extremity is quite different from the spatulate form of that of *I. bernissartensis*.

The Ischium.—The ischium is hammer-headed in form; its preaxial end is not nearly as robust as the postaxial, which is much thickened

[1] L. Dollo, "Première Note sur les Dinosauriens": Bull. Mus. R. Hist. Nat. Belg., vol. i, pl. ix, fig. 1.

for articulation with the ilium. The area between these extremities and the obturator process is basin-shaped. The obturator process is strongly developed and produced some distance from the shaft. The extremity is expanded and curved. The postaxial border of the whole bone is thicker than the preaxial, which is compressed into a thin edge. The shaft is twisted so that the preaxial margin becomes ventrally postaxial. The ventral extremity of the shaft is expanded pre-postaxially.

Determination of the Specimen.—These remains belonged to an individual exceeding the dimensions of *I. bernissartensis*, which would appear to preclude their identification with *I. mantelli*, for all the bones of the latter found either in England or at Bernissart have been nearly equal in size and much smaller and more graceful than those of *I. bernissartensis.* But the characters of the bones now being considered are identical with those which have been ascertained from the type fossil from Maidstone and the specimen of Bernissart, and leave no doubt that they are one and the same species. These characters are the presence of five vertebræ in the sacrum, the form of the pre-acetabular portion of the pubis, and the position of the median trochanter in the middle third of the shaft of the femur. The figure of the pelvic bones and femur of *I. mantelli* given by Professor L. Dollo[1] admirably represents the bones under review, and consequently they differ from the figure (fig. 4) of the same bones of *I. bernissartensis* given on the same plate. I was surprised to find that no detailed description and measurements of the sacrum and bones of the pelvis or illustration of the sacrum of either of the *Iguanodons* of Bernissart had been published, and I recently wrote to Professor L. Dollo, who informed me that he was at the present time engaged on a monograph in which they would appear, and also that in reality there is only one specimen that belongs with certainty to *I. mantelli* in the collection of Bernissart against more than twenty of *I. bernissartensis.*

Sundry measurements have been given, and before discussing the questions arising from their great dimensions it will be well to compare them with those of the present specimen.

The length of the pubic bone from the axis of the acetabulum in the several specimens is—

	I. mantelli.	*I. bernissartensis.*
	mm.	mm.
Bernissart example[2] . . .	400	700
Atherfield example . . .	720	

The length of the femur—

Bernissart examples[2] . . .	710	1080[3]
London (type-specimen)[2] . .	810	
Atherfield example . .	1158	

These figures prove a specimen of *I. mantelli* even greater in size than *I. bernissartensis*, and the lightness, gracefulness, and smallness

[1] L. Dollo, "Première Note sur les Dinosauriens": Bull. Mus. R. Hist. Nat. Belg., vol. i, pl. ix, fig. 1.

[2] Loc. cit., p. 164.

[3] R. Lydekker, B.M. Cat. Foss. Rep. Amp., 1888, pt. i, p. 202.

of skeleton can no longer be used as characters separating the two species. Thus it becomes a moot point whether the differences to be found in the skeletons of the two forms are not after all sexual, for the type is too marked to be a case of individual peculiarities and the divergent characters do not seem sufficiently great to be of specific value.

Mr. G. A. Boulenger[1] thought that the presence of six vertebræ in the sacrum of *I. bernissartensis* and five in that of *I. mantelli* proved the former a different species from the latter, but M. P. J. Van Beneden[1] held that the variation in the number was only due to individual differences, and that the number varied in Dinosaurs from four to six. Professor L. Dollo[1] later strongly supported the conclusions of Mr. G. A. Boulenger, considering that the obliteration of the cranial sutures and of the neuro-central suture of the vertebræ and the presence of a foramen in the coracoid of the small form, which had obviously communicated during youth with the exterior, excluded the idea of making them young individuals, and that therefore the large form could not thus represent the adult state of the small. Neither did he think that the divergences could be explained by individual variations, and although the smaller size, greater gracefulness, and the reduction of the thumb might be interpreted as sexual variations, the different form of the pelvis and the number of the sacral vertebræ would not admit of this interpretation. Therefore he concluded that individual variations and sexual characters were insufficient to explain the two forms.

With regard to the specimen of the sacrum in the British Museum, No. 37685, Hulke[2] many years ago doubted its belonging to *I. mantelli*, and after an examination of it I am convinced that he is correct.

The presence of only five sacral vertebræ in the form known as *I. mantelli* may possibly be connected with the situation of the median trochanter in the middle third of the shaft of the femur. Such a position by curtailing the length of the caudo-femoral muscle would not allow so great a stride as in *I. bernissartensis*, where it is placed in the lower third. The swaying of the ponderous tail would be less, and consequently there would be a decreased strain on the sacral vertebræ. In *I. bernissartensis* the greater stride and probably increased activity necessitated more rigidity in the sacral region, the result being six instead of five sacral vertebræ in that form. Moreover, I suggest that *I. mantelli* was the female and *I. bernissartensis* the male of the same species, and that this Dinosaur was viviparous. There is evidence that some were, for Marsh[3] declares that there is an embryo within the ribs of the type-specimen of *Compsognathus*, and it is a well-known fact that among the Ichthyopterygia, *Ichthyosaurus* was. If this were the case in *Iguanodon*, the differences found in the sacrum, pelvis, and femur need no further explanation. The expanded preacetabular extremity of the pubic bone into a large circular plate in *I. mantelli* is strikingly different from the spatulate form of *I. bernissartensis*. Is it not possible that

[1] *Vide supra.*
[2] J. W. Hulke, Quart. Journ. Geol. Soc., vol. xxxvi, p. 447, 1880.
[3] Marsh, *Amer. Journ. Sci.*, ser. III, vol. xxii, p. 340.

this expansion was an adaptation for the express purpose of insuring protection and support for the embryo? During the swing of the tail from side to side the body must have swayed in unison, and without a stiff lateral stop the embryo would have been compressed and distorted by constant thrust against the walls of the abdomen, so that injury would have occurred.

There was no symphysial union of the pubes and ischia, and the pubic bone has in all the Orthopoda a decided deepening at some portion of its length and is directed more forward than downward. The inner trochanter of the femur of *Iguanodon* is so much more developed than in other genera that the vertical expansion of the pubis would seem to have a relation to the swaying of the viscera caused by the peculiar bipedal progression of the reptile.

In the Theropoda the median symphysial union of the pubes and its prolongation along the lower anterior border formed, together with the fused ischia, a cradle for the embryo, so that an expansion of the pubic bone was not necessary.

Moreover, the position near the proximal end of the femur and weakness of the inner trochanter seem to show that in these reptiles the waddling was not nearly so great as in *Iguanodon*, and it is a question whether the Theropoda were really habitually bipeds. In the Sauropoda we find the same cradle-like pelvis, which would be more suitable for the protection of the embryo and for quadrupedal habits.

If *I. mantelli* is the female of *I. bernissartensis*, then the extent of the nares and the length of the tibia are features which are due to sexual divergence. In regard to the strange circumstance that at Bernissart the small form was found apart from the large forms, it does not seem a more remarkable coincidence than that every specimen of *I. mantelli* found up to the present has been smaller than *I. bernissartensis*.

Therefore the conclusion appears reasonable that the osteological variations are sexual and that *I. bernissartensis* is a synonym of *I. mantelli*.

In conclusion, the evidence seems to prove—

1. That *I. mantelli* attained the dimensions of *I. bernissartensis*.
2. That the differences found in the forms of the pelvic bones is probably sexual, an adaptation for the preservation of the embryo.
3. That *I. bernissartensis* is a synonym of *I. mantelli*.
4. That not only the body of the *Iguanodon* (as shown by Professor L. Dollo) is a lever of the first kind, but the bones of the pelvis comprise one also.
5. That the ventral expansion of the pubes and ischia was to give greater leverage power.
6. That the direction and ventral separation of the pubes and ischia were adapted for the sagging of the visceral mass when adopting the erect attitude.
7. That the prolongation and the recurving of the ischia were for the support of that mass when in that position.
8. That in the Theropoda, Orthopoda (sections *Stegosauria* and *Ceratopsia*) the upright position was seldom assumed.

9. That only in the Orthopoda high specialization of the pelvis had been obtained.

10. That the pelvis of *Triceratops* and *Stegosauria* show an incipient stage towards bipedal progression and not a secondary return to quadrupedal habits.

V.—Palæontological Notes from the Manchester Museum: On Mollusca from the Lancashire Coal-measures.

By J. Wilfrid Jackson, F.G.S., Assistant Keeper, Manchester Museum.

In re-arranging the large collection of Coal-measure fossils in the Manchester Museum I have had occasion to revise a number of species (notably in the Wild Collection) which have been recorded in the past under determinations which are now obsolete or erroneous. The object of this communication is to give a few critical remarks on these, as well as to place on record several hitherto unrecorded forms from the Lancashire Coal-field.

Cephalopoda.—The Nautiloid section of this class has already received some attention at the hands of Dr. W. Hind [1],[1] with the result that three new Lower Coal-measure forms have been discovered and some of Wild's former incorrect identifications rectified. Particulars of these will be found in Dr. Hind's paper; it will therefore be unnecessary to deal with them again here.

Two further Nautiloids, not dealt with by Dr. Hind, were also figured by Wild, from the Lower Coal-measures, in his paper [2]. These were given in his "Reference to the Plates" as "*Nautilus temnocheilus* [pl. i, figs. 2 and 3]. Roof of the Bullion Coal, Carre Heys, Colne", and "*Nautilus subsulcatus*, Salter [pl. ii, fig. 5; pl. iii, fig. 3]. Roof of the Bullion Coal, Townhouse, near Colne". No descriptions, however, accompanied the figures. Both these specimens are now in the Wild Collection (M.M.), and I have recently carefully examined them. One of the two examples referred to, "*N. temnocheilus*" (Wild's fig. 2), is a young shell consisting of one or two inner whorls displaying the sutures; this appears to be referable to *Solenocheilus cyclostomus* (Phil.), in which Dr. Hind agrees with me. The original of Wild's fig. 3, which is only a fragment of a whorl, together with another similar example in the Kay-Shuttleworth Collection (M.M.), are also to be referred to Phillips' species. With regard to "*Nautilus subsulcatus*", this has proved on critical examination to be an entirely new species of *Temnocheilus*.

Mr. H. Bolton, in his *Palæontology of the Lancashire Coal-measures* [3, p. 394] (compiled mainly from material in the Manchester Museum), gives a list of Nautiloid forms in the Lower Coal-measures as follows: *Ephippioceras costatum*, *E. clitellarium*, *Cœlonautilus subsulcatus*, *C. quadratus*, *Pleuronautilus falcatus*, *Temnocheilus concavus*, and *T. carbonarius*, stating that he believes examples of most of these species are in the Manchester Museum. The Museum, however, does not appear to possess authentic examples of any of these species from the Lancashire Coal-field, but *E. clitellarium* is represented by some

[1] These numbers refer to the bibliography at end of paper.

fragments from the Coal-measures of Madeley, Salop, and from the Pendleside Series of the Vale of Todmorden; *Pleuronautilus falcatus* and *Temnocheilus carbonarius* by specimens from Coalbrookdale.

Regarding the two species of *Cœlonautilus*, one of Wild's specimens, as has been shown above, was originally figured as *Nautilus subsulcatus* and remained in our collections under this name until recently; it has since been determined as a new species of *Temnocheilus*.

The inclusion of *C. quadratus* as a Coal-measure fossil (though recorded from Coalbrookdale) induced me to carefully look over our collections, with the result that I discovered a specimen in the "Kay-Shuttleworth Collection" labelled and registered as this species and as coming from the "Lower Coal-measures, Burnley". An examination, however, of the matrix, which is a black limestone, convinced me that some mistake had been made in the horizon of this fossil. In order to verify the identification of the species I submitted the specimen to Mr. G. C. Crick, who kindly determined it as follows: "*Cœlonautilus* aff. *quadratus.* Has some resemblance to *C. gradus*, Foord, but seems to come nearest to *C. quadratus* (J. Fleming)." At the same time he identified two other species on the same slab. These associated species are *Prolecanites serpentinus* and *Glyphioceras crenistria.* I have since exposed a specimen of *Posidoniella lævis* and what looks like the anterior end and umbo of a Lamellibranch which is very reminiscent of a Silurian *Grammysia.*

Dr. W. Hind has also seen the specimen, and remarks that it is "not unlike one of the bands of the Great Limestone of Weardale where *Cœlonautilus quadratus* occurs". Questioned further as to its probable Pendleside age, he says "the group suggests a lower horizon than Pendleside, though *Posidoniella lævis* would point to a Pendleside horizon". He quite agrees with me in thinking "not Coal-measures", but considers, like myself, "Black Hall, Bolland" as a possible locality whence the specimen was originally obtained. Two of the species, *Prolecanites serpentinus* and *Posidoniella lævis*, have already been recorded from the Pendlesides of that place [4], but the two other species are new to the list.

Pleuronautilus pulcher, Crick.—The Manchester Museum recently obtained a Nautiloid from Mr. D. M. S. Watson, who collected it from the Lower Coal-measures at Stalybridge, its horizon being "over the 1st coal". This specimen, which is an immature shell displaying the sutures very clearly, has been examined by Dr. Hind and Mr. Crick and pronounced to be *Pleuronautilus pulcher*, Crick. This discovery is interesting, as hitherto the species has only been recorded from the Pendleside Series near Hebden Bridge [5], and from the North Staffordshire Coal-field: 71 feet below the Four-feet Coal, Cheadle [6, p. 541, pl. xxxvi, fig. 3].

Glyphioceras aff. *reticulato* (J. Phillips).—Up to the present time the only record for *Glyphioceras reticulatum* in the Lancashire Coal-measures appears to be that given by Hull [7][1] as follows: "*Goniatites reticulatus*, Phill. Above Lower Lomax, Bury (just beyond the north-east edge of 1 inch map), opposite Broad Oak Mill. Above Gannister Coal."

[1] Referred to later by Bolton, Hind, and Crick.

In working through the "Mark Stirrup Collection" in the Manchester Museum I came across a specimen of a reticulate *Glyphioceras* from the "Upper Foot coal, Bacup", which Mr. Crick has kindly confirmed as *Glyphioceras* aff. *reticulato*, thus constituting a further record.

The species is recorded by Dr. Hind [6, p. 538] from below the Gin Mine Coal, Nettlebank (North Staffordshire Coal-field).

Glyphioceras aff. *striolato* (J. Phillips).—In 1905 the Manchester Museum obtained a number of 'roof nodules' or 'baum pots' from the Upper Foot Mine, Shore, Littleborough, and one of these nodules, on development, has yielded a remarkably large form of a *Glyphioceras* which measures 94 mm. in diameter. The specimen is slightly damaged and somewhat crushed in places, but on the whole is remarkably well preserved and shows the ornamentation of the test to great advantage. No sutures or constrictions, however, are visible. In general appearance it seems to come very near to *Glyphioceras striolatum* (J. Phillips) [=*diadema*, Beyrich (in part)], a large example of which, measuring 66 mm. in diameter, is figured by Messrs. Foord and Crick from Chokier (Belgium) [8].

Glyphioceras diadema has been recorded by Mr. Bolton from the Lower Coal-measures of Lancashire [3, pp. 396 and 413] as follows: "*Glyphioceras* (*Goniatites*) *diadema*. This species is recorded by Messrs. Crick and Foord from the Coal-measures of Rochdale. From the description of the specimen (C. 5098, Brit. Mus.) there is little doubt that the horizon is that of the Bullion or Upper Foot Seam."

Lamellibranchia.—It is much to be regretted that the Mollusca Committee of the Manchester Geological and Mining Society have included in their published list [9] several forms of bivalve mollusca from the Lancashire Coal-measures without first verifying the various records, as this mars what might otherwise have been a useful piece of work. Furthermore, it also leads one to infer, in several cases, the presence of 'marine bands' at the various horizons against which the species are placed.

The following are the chief revisions that it has been found necessary to make, more especially in the Wild Collection, upon which a large part of the above list was based.

"*Schizodus deltoideus*," from the roof of the Bullion Coal, Carre Heys, Colne (Wild and Kay-Shuttleworth Collections), are now regarded as *S. antiquus*, Hind. They compare favourably with the originals of Hind's fig. 27 of pl. xviii [10], now in the Manchester Museum. The specimen figured by Wild [2, pl. ii, fig. 7] as "*Anthracosia*, new angular sp." is considered and figured by Dr. Hind as a young example of *S. antiquus* [10, pl. xix, fig. 6].

"*Posidonomya gibsoni*."—This is a term which has been used in Lancashire for two different shells, viz. *Posidoniella lævis* and *P. minor*. Its use, therefore, should be discontinued, as suggested already by Dr. Hind, in order to avoid further confusion. Wild's specimen (Manch. Mus., W. 630), figured as *P. gibsoni* [2, pl. ii, fig. 8], is *P. lævis*. Its horizon and locality is Sholver, near Oldham, Bullion Coal.

"*Nucula striata*."—This name appears in the *Catalogue of Fossils in* *the Cabinet of Mr. George Wild, etc.* [2, p. 396], but there appears to be no specimen under that name in the Wild Collection in the Manchester Museum. There is a *Nucula*, however, in the collection from Carre Heys, Colne (roof of the Bullion Coal), which was figured by Wild as "*Nucula* sp." [2, pl. ii, fig. 3]. This specimen is not very well preserved, and is mounted in Canada balsam on a micro-slide, so that its specific characters are difficult to make out. It strongly resembles *Nucula gibbosa*, Fleming, and in all probability is to be referred to that species.

"*Modiola*."—This name was used by Wild [11, p. 184, and 12, p. 462] to denote certain modioliform bivalves occurring in "dark shale over the Low Bottom Bed at Fulledge Colliery, Burnley", and in the "black shale roof over the $5\frac{1}{2}$ inches coal at 636 yards, Bardsley Colliery". Specimens from these and other localities, preserved in the Manchester Museum, and labelled as "*Modiola*" by Wild, prove to be young forms of *Anthracomya*.

"*Orthonota*."—The same remarks apply here as to the above "*Modiola*". Wild's specimens from the Low Bottom Bed at Fulledge Colliery, Burnley, labelled as "*Orthonota*", are young forms of *Anthracomya wardi*, which species is already recorded for this horizon by Mr. Bolton [3, p. 597], though omitted from the Mollusca Committee's list.

Tellinomya robusta, Bolton [13, p. 5, pl. v, figs. 6–8*a*].—After careful and prolonged study of the actual specimens on which this species was founded, as well as others so named in the Manchester Museum and Chadwick Museum, Bolton, I have come to the conclusion that they are merely interior casts of a species of *Carbonicola*. They present no nuculoid characters at all, but, on account of their tumidity, might very well be casts of such species as *Carbonicola turgida*, with which they have been carefully compared.

The same remark applies to the "*Tellinomya*, n.sp." of Bolton's later paper [3, p. 589], the specimens being casts of either large forms of *Carbonicola turgida*, such as those obtained from the "Stubbs Coal", Bardsley, or of *C. gibbosa*, or even *C. robusta*. In fact, a specimen in the Chadwick Museum, Bolton, from Watergate Colliery, is labelled as "*Carbonicola robusta*".

All the specimens I have so far examined of "*Tellinomya robusta*" and "*Tellinomya*, n.sp." show signs of very considerable wear by water action.

Chænocardiola footii, Baily.—This species was recorded by Dr. Hind [10, p. 475] from the Coal-measures of Burnley, the specimen on which this record was based being in the "Kay-Shuttleworth Collection" (Manchester Museum, L. 2088). The specimen was, until quite recently, stuck down on a cardboard mount, but on detaching it I discovered a label on its underside bearing the legend "Yoredale Shales? Pendle?" This induced me to carefully examine the matrix, which I found to be a black limestone. I have, therefore, no hesitation in stating that it is not a Coal-measure fossil at all, but is, in all probability, to be referred to the same horizon as the *Cœlonautilus* aff. *quadratus* mentioned previously, i.e. the Pendleside Series of Black Hall, Bolland.

Anthracomya phillipsii (Williamson).—Some extraordinary misunderstanding appears to have taken place here with regard to the type-specimen of this abundant Upper Coal-measure form. The example described and figured as the type by Dr. Hind [14, p. 263, pl. x, fig. 27; 15, p. 121, pl. xvi, fig. 10] (Manchester Museum, L. 10106) is labelled on its underside as coming from Ardwick and the matrix is a red shale, whereas Williamson in his original diagnosis [16, p. 351] gives the *Spirorbis* limestone shale of Pendlebury as the horizon and locality whence Dr. C. Phillips obtained the specimens on which the species appears to have been founded. The Ardwick specimen, therefore, can only be regarded as the original of Hind's figures and not as the type-specimen. I have been unable, so far, to trace the original specimen, or, in fact, any examples from the Pendlebury district in the Manchester Museum.

Gasteropoda.—*Raphistoma* (?) *ornata*, Bolton [13, p. 6, pl. v, fig. 10]. The specimen (Manchester Museum, L. 3494) on which this species was founded represents quite a young shell about 1½ to 2 whorls beyond the nepionic stage, and can scarcely be referred to the genus *Raphistoma*, Hall, as defined by De Koninck [17, p. 133]. In my opinion, judging from the fragmentary material at my disposal, it seems to possess greater affinity with the genus *Turbonellina*, De Koninck [17, p. 76], and in all probability is referable to a young stage of one or other of the species placed in this genus by De Koninck. One species, *Turbonellina formosa*, De Kon., has already been recorded by Dr. Hind [6, p. 532] from the marine band below the Gin Mine Coal at Nettlebank (North Staffordshire Coal-field). The horizon and locality of the Manchester Museum specimen is Lower Coal-measures (Bullion Coal), Bacup, Lancs.

Bibliography.

1. Proc. Yorks. Geol. Soc., vol. xvii, pt. ii, p. 97 et seq., pls. iii, v, and vi, 1910.
2. Trans. Manch. Geol. Soc., vol. xxi, pt. xiii, p. 400, pls. i–iii, 1892.
3. Ibid., vol. xxviii, 1904.
4. Quart. Journ. Geol. Soc., vol. lvii, p. 353, and Appendix B, facing p. 402, 1901.
5. Proc. Malac. Soc., vol. vi, pp. 15–20, pl. ii, 1904.
6. Quart. Journ. Geol. Soc., vol. lxi, 1905.
7. Geol. Surv. Mem., *Geology of the Country around Bolton-le-Moors*, p. 35.
8. Catal. Foss. Ceph. Brit. Mus., pt. iii, p. 203, fig. 98, 1897.
9. Report to the Council, September, 1910.
10. Mon. Brit. Carb. Lamell. (Palæontographical Society), vol. i, 1896–1900.
11. Trans. Manch. Geol. Soc., vol. iv, 1863.
12. Ibid., vol. xviii, 1886.
13. Mem. and Proc. Manch. Lit. and Phil. Soc., vol. xli, No. vi, 1897.
14. Quart. Journ. Geol. Soc., vol. xlix, 1893.
15. Monog. *Carbonicola*, etc. (Pal. Soc.), 1895.
16. Philos. Mag., vol. ix, 1836.
17. Faune du Calc. Carb. Belg., pt. iii, 1881 (Ann. Mus. Roy. d'Hist. Nat. Belg., vol. vi).

NOTICES OF MEMOIRS.

I.—On the Importance of Africa in Vertebrate Palæontology.[1] By C. W. Andrews, D.Sc., F.R.S. (British Museum, Natural History).

It is a remarkable circumstance that Africa has long been admitted to be one of the oldest land-areas in the world, portions of it not having been submerged since the Permian period or even earlier. The Reptilia from the Permian and Triassic beds of South Africa are of exceptional interest and importance, because they not only include forms which show relationships with the Amphibia, but also give a clue to the manner in which the reptiles gave rise to the mammals. The fact that the mammals originated from these reptiles may be regarded as demonstrated; this is of particular importance, because, if it can be certainly shown that the Mammalia really originated in Africa, and if parts of that continent have been land since this took place, then it is highly probable that somewhere or other there will be found mammalian remains of various periods, linking up the primitive Triassic or early Jurassic mammals with the modern types. Unfortunately, so far, no Secondary mammalian remains have been found.

When we come to the Tertiary period the case is different, primitive members of the orders Proboscidea, Hyracoidea, and Sirenia having been discovered in the Middle and Upper Eocene beds of the Fayum district of Egypt. These same beds have also yielded remains of animals which show that the anthropoid apes and toothed whales probably originated in the same region. Besides these there are a number of remarkable forms which seem to have died out without leaving any descendants in the fauna of to-day. One of these, *Arsinoitherium*, was a huge hoofed animal carrying a pair of large horns on the nose, and quite unlike anything known elsewhere.

Up to this period Proboscidea are known only from Egypt, but between the Upper Eocene and the Lower Miocene, the next horizon at which they have been found, they had spread over much of the world, having passed out of Africa along some land connexion with Europe or Asia, which broke down the isolation of that part of Africa in which they had originated; the anthropoid apes, Hyraxes, and other members of the same fauna, no doubt spread north with them. In the lowest Miocene beds of Europe and India the Proboscidea are represented by two distinct types. One, *Tetrabelodon*, is really a Palæomastodon with its peculiarities exaggerated; the other form, *Dinotherium*, is very different and presents peculiarities not found in any other of the elephants. In deposits of the same age at Mogara, in Egypt, only *Tetrabelodon* occurs, nor was it known till quite recently that *Dinotherium* had existed in any part of Africa. Last year, however, Mr. C. W. Hobley sent to the British Museum a fragment of a mandible with molars which undoubtedly belongs to a small species of *Dinotherium*, closely similar to *Dinotherium*

[1] From the Journal of the East Africa and Uganda Natural History Society, vol. ii, No. 4. (Abstract.)

cuvieri, a species found in the Lower Miocene beds of France. This specimen was collected by the late Mr. Botry Piggot at Karungu, near the south-eastern shore of Lake Victoria Nyanza, and is the first early Tertiary mammal recorded from tropical Africa. It is of the greatest interest, because it proves the possibility, and even the probability, of mammalian faunas of various ages occurring in that region, and also shows that the separation of *Dinotherium* from the rest of the Proboscidean stock most likely took place in Africa, where the intermediate links may therefore be expected to be found. The finding of this specimen shows what great possibilities of the discovery of completely new forms of extinct animals are afforded by British East Africa. An expedition to German East Africa has already found remains of a gigantic Dinosaur, some of the bones of which are about twice the size of those of the well-known *Diplodocus carnegii*, a reptile which was about 80 feet long. Now this discovery of a new mammalian fauna of Miocene age gives great hopes that in the near future important additions to our knowledge of this region may be made. It is greatly to be desired that anyone finding teeth or bones (or even fragments of them) that appear to be in a fossil condition, should send them to the British Museum for determination; for even though the specimens themselves may not be very good, they may be sufficient to determine whether further collecting on the spot would be likely to lead to valuable results.

II.—BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, DUNDEE, 1912.

The Relation between the Cambrian Faunas of Scotland and North America.

Address to the Geological Section by B. N. Peach, LL.D., F.R.S. (President of Section C).

Introduction.

Ever since the announcement made by Salter in 1859 that the biological affinities of the fossils found in the Durness Limestone are more closely linked with American than with European forms, the relation between the older Palæozoic faunas of Scotland and North America has been a subject of special interest to geologists. The subsequent discovery of the *Olenellus* fauna in the North-West Highlands furnished striking confirmation of Salter's opinion. This intimate relationship raises questions of prime importance bearing upon the sequence and distribution of life in Cambrian time in North America and North-West Europe, on the probable migration of forms from one life-province to another, and on the palæogeographical conditions which doubtless affected these migrations.

On this occasion, when the British Association revisits the border of the Scottish Highlands, it seems appropriate to refer to some of these problems. With this object in view I shall try to recapitulate briefly the leading features of the life-history of Cambrian time in Scotland and North America, to indicate the relation which these life-provinces bear to each other, and, from these data, to draw some inferences regarding the probable distribution of land and sea which then obtained in those regions.

The two great rock groups in Scotland that are universally admitted to be older than Cambrian time are the Lewisian Gneiss and the

Torridon Sandstone. The Lewisian Gneiss, as mapped by the Geological Survey, consists mainly of igneous rocks, or of gneisses and schists of igneous origin. But, in addition to these materials, we find, in the Loch Maree region, schists of sedimentary origin, comprising siliceous schist, mica-schist, graphite-schist, limestone, chert, and other sediments. The association of graphite-schist with limestone and chert suggests that we are here dealing with rocks that were formed at or near the extreme limit of sedimentation, where the graphite, the limestone, and the chert were probably accumulated from the remains of plankton. But this assemblage has been so completely altered into crystalline schists that all traces of original organic structure in them have been destroyed.

The Torridonian strata were evidently accumulated under desert or continental conditions, and could therefore furnish little or no evidence bearing upon the development of marine life. That life existed, however, is clear from the presence of phosphatic nodules, containing remains of cells and fibres of organic origin, in the upper division of the system, and from the presence of worm burrows and casts in the Diabaig Beds (Lower Torridon).

Geologists are familiar with the fact that the Cambrian faunas all over the globe present highly specialized types belonging to most of the great groups of marine invertebrate life. Scotland is no exception to this general rule. For the fossils prove that their ancestors must have had a long history in pre-Cambrian time.

The Cambrian Fauna of Scotland.

Beginning with the false-bedded quartzites forming the basal subdivision of the Cambrian strata in the North-West Highlands, we find no traces of organic remains in them, except at one locality, where worm casts (*Scolithus linearis*) were obtained. In the upper subdivision of the quartzites—the pipe-rocks—the cylinders of sand are so numerous that the beds have been arranged in five sub-zones, based on a definite order of succession of different forms probably of specific value. One of them, *Arenicolites* of Salter, may be of generic importance. Worms of this habit are confined to comparatively shallow water, and therefore near the shore-line. Their occurrence helps to confirm the belief that the quartzites were laid down on an ancient shelving shore-line during a period of gentle subsidence. Their presence also indicates the existence of plankton, from which they derived nourishment. Besides the relics of these burrowing Annelids, one of the sub-zones of the pipe-rock has yielded specimens of *Salterella* (*Serpulites Maccullochii*)—a tubicolar Annelid, which becomes more abundant in the overlying fucoid beds, serpulite grit, and basal limestone, where it is associated with *Olenellus* and other typical Lower Cambrian forms.

The fucoid beds, which immediately overlie the pipe-rocks, consist chiefly of shales and brown dolomitic bands, with intercalations of grit locally developed. This type of sedimentation indicates that the mud-line was superimposed on the shore-line by subsidence. With this change of conditions there is a change of organisms, for though the burrowing forms (*Scolithus*) are still to be found in the sandy layers, the most characteristic types are those occurring along the bedding planes, known under the name of *Planolites* (Nicholson). They are very varied forms, and were probably produced by many types of errant Annelids. The tubicolar Annelids are represented by *Salterella, Coleoloides*, and *Hyolithes*—an organism which perhaps links the worms with the hingeless Brachiopods. This suggestion gains additional support from the researches of Dr. Walcott in the Middle Cambrian rocks of Canada. It is interesting to note that small Annelids seem to have bored the spines of dead Trilobites. Walcott has found similar borings in the chetæ of Annelids in the Middle Cambrian rocks of Canada.[1]

[1] Smithsonian Misc. Coll., vol. lvii, No. 5, p. 125, 1911.

The researches of Dr. Walcott have proved beyond doubt that representatives of nearly all the divisions of the Annelids are entombed in the Middle Cambrian rocks of Mount Stephen, in British Columbia. We may therefore reasonably infer that the worm casts of *Scolithus* type found in the North-West Highlands are due to Annelids. He has also shown that worm-like Holothurians are to be found in the same beds.[1] In this connexion it may be observed that some of the recent Holothurians have much the same habit of obtaining nourishment from the sands and silts containing organic matter.

Fragments showing the characteristic microscopic structures of the plates and ossicles of Echinoderms have been found in the fucoid beds. These are probably Cystidean. Hingeless forms of Brachiopods also occur, among which may be mentioned *Paterina labradorica* and *Acrothele subsidua.* The type of *Acrothele* suggests a genetic descent from such a tubicolar worm as *Hyolithes.* Of the Gasteropods, only one specimen, belonging to a sub-genus of *Murchisonia,* has been obtained at one locality in Skye. *Helenia bella,* a curved calcareous tube, open at both ends, doubtfully referred to the Dentalidæ by Walcott, is comparatively plentiful. It occurs also in the *Olenellus* zone in Newfoundland.

But the organic remains that render the fucoid beds of exceptional interest and importance are the Trilobites, because they clearly define the horizon of this zone in the Cambrian system and display strong affinities with American types. They are represented by five species and varieties of *Olenellus,* very closely resembling the forms in the Georgian terrane, or *Olenellus* zone, on the east and west sides of the North American continent. The genus *Olenelloides* has also been recorded from these beds. The Crustacea are represented by Phyllocarids, among which we find *Aristozoe rotundata,* likewise characteristic of the *Olenellus* zone of North America.

Next in order comes the serpulite grit, which indicates a recrudescence of the pipe-rock conditions of deposition, and presents the *Scolithus* type of Annelid borings. From the diameter of the pipe and the depth of the burrow it is probable that the worm may have belonged to a different species from any of those whose casts are to be found in lower horizons. This large variety is associated with smaller and more irregular worm casts which have often weathered out and leave the rock honeycombed with hollow casts. The characteristic form from which the zone takes its name is *Salterella* (*Serpulites Maccullochii*). It occurs abundantly along certain calcareous layers that mark pauses in the deposition of the sand. This calcareous type culminates at the top of the zone, where there is a thick, carious, weathering band, crowded with specimens of *Salterella,* forming a passage bed into the calcareous shales at the base of the Durness dolomites. At one locality near Loch an Nid, Dundonnell Forest, Ross-shire, thin shales, intercalated in the serpulite grit, yielded a fine carapace of *Olenellus Lapworthi*—a form of frequent occurrence in the underlying fucoid beds. Professor Lapworth recorded the finding of *Orthoceras* and linguloid shells in the top part of this zone at Eireboll.[2]

Immediately above the serpulite grit in Eireboll and Assynt we find a few feet of dark calcareous shale, with iron pyrites, probably deposited at the limit of sedimentation. This layer, which is singularly devoid of organisms, ushers in the great succession of dolomites and limestones, upwards of 1,500 feet in thickness—perhaps the most remarkable type of sedimentation among the Cambrian rocks of the North-West Highlands. The Geological Survey has divided this calcareous sequence into seven well-marked groups, some of which have as yet yielded no fossils beyond worm casts. Attention will presently be

[1] Smithsonian Misc. Coll., vol. lvii, No. 3, 1911.

[2] Geol. Mag., 1883, p. 126.

directed to the absence of calcareous forms in many of the bands of dolomite and to the probable cause of their disappearance.

The thin calcareous shale just referred to is followed by dark-blue dolomite limestone, forming the basal portion of the Ghrudhaidh group. It contains sparsely scattered, well-rounded sand grains, with a bed about 3 feet thick, near the bottom, charged with *Salterella pulchella* and *S. rugosa.* In the overlying 20 feet of dolomite the sand grains gradually disappear, and the rock assumes a mottled character, due to innumerable worm casts of the *Planolites* type. Here a second layer, yielding *Salterella pulchella* and *S. rugosa,* supervenes, both forms occurring in the *Olenellus* zone of North America.

The brief summary of the palæontological evidence which has just been given clearly shows that the strata ranging from the middle of the pipe-rock zone to the upper *Salterella* band of the Durness dolomites represent in whole or in part the *Olenellus* zone of North America. Owing to the absence of fossils we have no means of deciding more definitely the base and top of the Lower Cambrian rocks of the North-West Highlands. All the quartzites lying below the middle of the pipe-rock, notwithstanding the absence of zonal forms, have been included in the Lower Cambrian division. This correlation receives some support from the remarkable discovery of Dr. Walcott, who found primitive Trilobites several thousand feet beneath the beds yielding *Olenellus Gilberti,* the form closely allied to the Highland Trilobites.

On the other hand, when we pass upwards for a certain distance from the *Salterella* bands the evidence is insufficient to establish the stratigraphical horizon of the beds. For, in the overlying strata comprising the remainder of the Ghrudhaidh group, the whole of the Eilean Dubh group, and the lower part of the Sail Mhor group, and consisting of dolomites, limestones, and cherts, with little or no terrigenous material, the only fossils that can be shown to be due to organisms are worm casts of the nature of *Planolites,* although the limestone and chert may have originated from the debris of the calcareous and siliceous organisms of the plankton. A noticeable feature of the Ghrudhaidh and Eilean Dubh groups is the occurrence in them of bands of brecciated dolomite on several horizons, which do not imply any break in the continuous sequence of deposits. The total thickness of this portion of the Durness dolomites and limestones, yielding no fossils beyond worm casts, amounts to 350 feet.

But in the upper part of the Sail Mhor group siliceous and calcareous organisms of a higher grade make their appearance. Among the former we find the *Rhabdaria* of Billings. The calcareous forms are represented by (1) Gasteropods, including a single specimen of a Murchisonid, two species of a Pleurotomarid (*Euconia Ramsayi* and *E. Etna*) of a type occurring in the calciferous rocks of Newfoundland and Canada ; (2) Cephalopods, comprising two slightly bent forms with closely set septa and wide endogastric siphuncles, showing affinities with those of *Endoceras* and *Piloceras* ; (3) Arthropods, represented by the epitome of a large asaphoid Trilobite resembling that of *Asaphus canalis* of Conrad. This evidence is insufficient to determine the exact horizon of these beds, but clearly indicates that we are no longer dealing with Lower Cambrian strata. The Cephalopods are like those found in the Ozarkic division of Ulrich (Upper Cambrian), in North America. According to Schuchert, the Cephalopods with closely set septa are of Cambrian type and older than those of the Beekmantown terrane of American geologists. On the other hand, the asaphoid type of Trilobite is suggestive of a somewhat higher horizon.

No fossils have been found in the overlying Sangomore group, about 200 feet thick, which consists mainly of granular dolomite, with bands of chert, some being oolitic, together with thin fine-grained limestones near the top.

Above this horizon, at a height of over 800 feet above the top of the *Olenellus* zone, we encounter the great home of the fossils peculiar to the Durness Limestone in the Balnakeil and Croisaphuill groups. The former consists mostly of dark limestones, with nodules of chert, and, with a few alternations, of white limestone bands. A few thin layers are charged with worm casts. The overlying group is more varied, the lower part being composed of dark-grey limestones full of worm casts, and with some small chert nodules arranged in lines; the middle portion, of dark granular and unfossiliferous dolomite; and the upper part, of massive sheets of fossiliferous limestone full of worm casts. The total thickness of these two groups in Durness is about 550 feet.

These two subdivisions have yielded over twenty genera and about one hundred species. In Durness sixty-six species have been obtained from the Balnakeil group alone, fifteen of which have not as yet been found in the overlying Croisaphuill group, thus leaving fifty-one species common to both divisions. The Ben Suardal limestones in Skye, which were mapped by the Geological Survey as one division, are regarded, on palæontological grounds, as the equivalents of both these groups. Owing to the number of species common to both subdivisions, the fauna will be here referred to as a whole.

Both siliceous and calcareous organisms are present in this fauna. Among the former we find *Archæoscyphia* (Hinde), described by Billings as *Archæocyathus,* an early Cambrian coral, but shown by Hinde to be a siliceous sponge.[1] The genus *Calathium* is represented by four species. Other genera and species of sponges occur, so that the siliceous nodules, which are very common in both groups, may be in great part due to them. In this connexion it may be mentioned that Hinde obtained sponge spicules from some of the nodules. Hinged Brachiopods have also been collected from these beds, and include *Nisusia* (*Orthosina*) *festinata*, *N. grandæva,* and *Camarella.*

But the characteristic feature of the fauna is the assemblage of calcareous Mollusca comprising Lamellibranchs, Gasteropods, and Cephalopods, showing a wide range of variation, and consequently a long ancestry. The Lamellibranchs, though represented only by two genera, *Euchasma* and *Eopteria* of Billings, with several intermediate forms, are of extreme interest, as they are only known to occur elsewhere in Newfoundland and Eastern Canada. The Gasteropods, however, furnish the largest number of species—about 48 per cent of the whole. The primitive Euomphalids, *Maclurea* and *Ophileta,* are most characteristic. The former genus has a large number of species, many of which are to be found in the Beekmantown Limestone of Newfoundland and Eastern North America. Only one of the species (*Maclurea Peachi*) is peculiar to Durness. Several species of *Ophileta* are found, some of which likewise occur in the Beekmantown Limestone. *Euomphalus* has also been recorded, while several forms belonging to the nearly allied family of the Turbinidæ, and placed in Lindström's genus *Oriostoma,* are also met with in the Beekmantown Limestone.

Murchisonids and Pleurotomarids number twenty-seven species and show a very wide range of variation. The chief sub-genera of the former are *Hormotoma* and *Ectomaria,* many species of which occur with remarkable variations. All the types of variation found in Durness are to be found in North America, and several of the species are common to both regions. The Pleurotomarids vary in a similar manner, the chief genera being *Raphistoma* and *Euconia*, and a form resembling *Hormotoma,* only with a shorter spire. Species belonging to each of these sub-genera are likewise common to both areas, while some are only known from the North-West Highlands.

The Cephalopods are of equal interest. They are also of primitive type, and, at the same time, show a wide range in form. The

[1] Quart. Journ. Geol. Soc., vol. xlv, p. 125, 1889.

prominent feature in the straighter specimens is the great width of the laterally placed siphuncle, which is generally furnished with endocones and organic deposits. The genus *Piloceras* is the most characteristic type, and shows this peculiar feature best. It has only been recorded from Scotland, Newfoundland, Canada, and the eastern States of North America. The following additional genera are represented, viz., *Endoceras,* chiefly by siphuncles in great variety, *Actinoceras, Cyrtoceras,* and, doubtfully, *Orthoceras.* Several forms have been attributed to *Orthoceras,* which, on re-examination, have been found to be the siphuncles of other genera, resembling American types described by Hall and Whitfield.

The whorled Nautiloids provisionally classed with the genus *Trocholites* of Conrad are represented by several distinct forms as yet unnamed.

The Trilobites are of rare occurrence in these two groups of dolomite and limestone. They are fragmentary and poorly preserved. This is doubtless one of the disappointing features connected with this remarkable assemblage of organic remains, for the presence of a zonal form would have helped to define the horizon of these beds. Only one species, *Bathyurus Nero* (Billings), has been identified, which also occurs in the Beekmantown Limestone of Newfoundland. The other Trilobite remains, though poorly preserved, have a Cambrian facies characteristic of North America.

In connexion with this fauna certain features have been observed which throw some light on the absence of calcareous organisms from thick zones of the Durness dolomite and limestone. In my detailed description of the palæontology of the Cambrian rocks of the North-West Highlands in the Geological Survey Memoir, I stated that "in most cases the septa and walls of chambered shells have been wholly or in part dissolved away, so as to leave only the more massive structures of the siphuncles, and worm castings are often found within the chambers where the septa have been preserved. These features seem to indicate that the accumulation of the calcareous mud in which the fossils were embedded was so slow that there was time for the solution of part of an organism before the whole of it was covered up".[1] There is good reason to believe that many organisms wholly disappeared by this process, so that it is reasonable to conclude that the fossils obtained from the Durness dolomites cannot be regarded as furnishing a complete life-history of the forms that originally existed in that sequence of deposits. Attention has already been called to the fact that beneath the two subdivisions now under consideration there are groups of dolomite and limestone which so far have yielded no organic remains beyond worm castings. And even in the important Croisaphuill group, with its fossiliferous zones, there are thick groups of dolomite which have furnished no calcareous organic remains. Obviously the palæontological record in this instance is glaringly incomplete, for we have no reason to suppose that the life of the time flourished in some of the calcareous zones and not in others.

The highest subdivision of the Durness Limestone, measuring about 150 feet in thickness (Durine group), has yielded two species of *Hormotoma*—viz. *H. gracilis* and *H. gracillima*—both of which occur in the two underlying groups. *H. gracilis* occurs in the Beekmantown, the Chazy, and the Trenton Limestones of America.

Before assigning any stratigraphical horizons to the fauna of the Durness dolomites, it is desirable, owing to the American facies of the fossils, to recapitulate the evidence bearing upon the life of Cambrian time in North America. But the Cambrian life-history of Scotland would be incomplete without a brief reference to the recent discovery of fossils along the eastern border of the Highlands.

[1] *Geological Structure of the North-West Highlands*: Geol. Surv. Mem., 1907, p. 380.

In 1911 Dr. Campbell announced in the GEOLOGICAL MAGAZINE that fossils had been found in the Highland border series north of Stonehaven, and, during this year, Dr. Jehu made a similar discovery in rocks belonging to this series near Aberfoyle. Papers on these subjects will be communicated to this section. For my present purpose it will be sufficient to indicate the nature of the fossils and the lithological characters of the rocks containing them.

The Highland border series north of Stonehaven and near Aberfoyle includes sheared igneous rocks, both lavaform and intrusive, with black shales, cherts, and jaspers. North of Stonehaven the fossils occur in thin, dark, flinty pyritous shale, while at Aberfoyle they have been found in shaly films at the edge of the chert bands. Several years ago Radiolaria were detected in the cherts between Aberfoyle and Loch Lomond. From time to time these Highland border rocks have been carefully searched for fossils, but until recently with little success, owing to the intense movement to which they have been subjected, resulting in marked flaser structure in all except the most resistant bands.

The fossils consist chiefly of horny, hingeless Brachiopods, Phyllocarid Crustacea, worm tubes, and the jaws and chetæ of Annelids. The genera of Brachiopods comprise *Lingulella, Obolus, Obolella, Acrotreta,* and *Linarssonia.* The association of these Brachiopods with Phyllocarid Crustaceans resembling *Hymenocaris* and *Lingulocaris* is suggestive of an Upper-Cambrian horizon—an inference which is supported by the absence of Graptolites.

In the published Geological Survey maps these Highland border rocks are queried as of Lower Silurian age. This correlation was based partly on their resemblance to the Arenig volcanic rocks and Radiolarian cherts of the Southern Uplands, and partly because, as shown by Mr. Barrow, they are overlain by an unconformable group of sediments, termed by him the Margie Series. The cherts, the green schists, and the Margie Series have shared in a common system of folding, and are unconformably surmounted by Downtonian strata near Stonehaven. Though the original correlation may not be strictly correct, it is probable, in my opinion, that representatives of both the Arenig and Upper Cambrian formations may occur in the Highland border series, and, further, that Upper Cambrian strata may yet be found in the Girvan area, as originally suggested by Professor Lapworth in correspondence with Dr. Horne.

The Cambrian Fauna of North America.

[We are unable, from want of space, to give the particulars here related by Dr. Peach, and therefore quote only the conclusions at which he has arrived.]

The palæontological evidence adduced regarding the relation of the Cambrian fauna of the North-West Highlands to that of North America leads to the following conclusions:—

1. The Lower Cambrian fauna of the North-West Highlands, distinguished by the genus *Olenellus* and its associates, is almost identical in character with that of the Georgian terrane of the western life-province of North America, and essentially different from the Lower Cambrian fauna of the rest of Europe.

2. No forms characteristic of the Middle Cambrian division, either of Europe or North America, have as yet been found in the North-West Highlands; but this division may be represented by the unfossiliferous dolomites and limestones of the Ghrudhaidh, Eilean Dubh, and the lower Sail Mhor groups.

3. The fossiliferous bands of the Sail Mhor group may be the equivalents of the lower part of the Upper Cambrian formation.

4. The Balnakeil and Croisaphuill groups of the Durness dolomites

and limestones contain a typical development of the molluscan fauna of the Beekmantown Limestone, belonging to the western life-province of North America. As the Beekmantown Limestone is succeeded by shales, with Arenig Graptolites, it follows, in accordance with British classification, that these groups must be of Upper Cambrian age.

5. The highest subdivision of the Durness Limestone (Durine) has not yielded fossils of zonal value, and the members of this group are not overlain in normal sequence by graptolite-bearing shale or other sediments.

Cambrian Palæogeography between North America and North-West Europe.

In attempting to restore in outline the distribution of land and sea in Cambrian time between North America and North-West Europe, reference must be made to various investigators whose researches in palæogeography are more or less familiar to geologists. Among these may be mentioned Suess, Dana, De Lapparent, Frech, Walcott, Ulrich, Schuchert, Bailey Willis, Grabau, Hull, and Jukes-Browne. The views now presented seem to me to be reasonable inferences from the palæontological evidence set forth in this address.

In the North-West Highlands there is still a remnant of the old land surface upon which the Torridonian sediments were laid down. There is conclusive evidence that the pre-Torridonian land was one of high relief. As the Torridonian sediments form part of a continental deposit it may be inferred that the Archæan rocks had a great extension in a north-westerly direction. The increasing coarseness of the deposits towards the north-west suggests that the land may have become more elevated in that direction. At any rate, the pile of Torridonian sediments points to a subsidence of the region towards the south-east, and probably to a correlative movement of elevation towards the north-west.

The sparagmite of Scandinavia is an arkose resembling the dominant type of the Torridon Sandstone; is of the same general age, and has evidently been derived from similar sources in the Scandinavian shield. In eastern North America coarse sedimentary deposits form part of the newer Algonkian rocks, which are still to be found rising from underneath the Cambrian strata in the region of the great lakes. These materials were obtained from the great Canadian shield, which must have formed a large continental area during their deposition.

It is reasonable to infer that these isolated relics of old land surfaces were united in pre-Torridonian time, thus forming a continuous belt from Scandinavia to North America. During the period which elapsed between the deposition of the Torridon Sandstone and the basement members of the Cambrian system a geosyncline was established which gave rise to a submarine trough, trending in an east-north-east and west-south-west direction, both in the British and North American areas. In the latter region it extends from Newfoundland to Alabama, its south-eastern limit being defined by the old land surface of Appalachia. The extension of this Appalachian land area in a north-east direction beyond the limits of Nova Scotia and Newfoundland was postulated by Dana and other American writers. This geosyncline remained a line of weakness throughout Palæozoic time, both in Britain and North America, which resulted in the Caledonian system of folding in Britain, and in the Taconic, Appalachian, and Pennsylvanian systems in North America. Hence it is manifest that the original shore-lines of this trough are now much nearer each other than they were in Cambrian time.

The Cambrian rocks of the North-West Highlands were laid down along the north-west side of this trough during a period of subsidence, for the great succession of Durness dolomite and limestone, with little or no terrigenous material, is superimposed on the coarser sediments of that formation. On the other hand, the Cambrian strata of Wales seem to have been deposited along the southern limit of this marine depression. The Archæan rocks that now constitute the central plateau of France may have formed part of its southern boundary. The extension of this land area towards the north-east may have given rise to the barrier that separated the Baltic life-province from that of Bohemia, Sardinia, and Spain. In my opinion, this southern land area in Western Europe was continuous across the Atlantic with Appalachia. For the life sequence found in the Cambrian rocks of New Brunswick is practically identical with that of Wales and the Baltic provinces, thus showing that there must have been continuous intercourse between these areas. Along this shore-line the migration of forms seems to have been from Europe towards America. On the other hand, along the northern shore the tide of migration seems to have advanced from America towards the North-West Highlands. The question naturally arises, what cause prevented the migration of the forms from one shore of this trough to the other? American geologists are of opinion that this is probably due to the existence of land barriers; but, in my opinion, it can be more satisfactorily accounted for by clear and open sea, aided by currents.

The south-western extremity of the American trough in Lower Cambrian time opened out into the Mississippian sea, which was connected with the Pacific Ocean, and stretched northwards towards the Arctic regions. Reference has already been made to Walcott's discovery in Nevada of the primitive Trilobite *Nevadia Weeksi*, from which he derives both branches of the Mesonacidæ, one branch linking *Nevadia*, through *Callavia, Holmia*, and *Wanneria*, with *Paradoxides*, the other connecting *Nevadia* with *Olenellus*, through *Mesonacis, Elliptocephalus*, and *Pædumias*.

In Nevada the genus *Holmia*, as already shown, is associated with the primitive type *Nevadia*. *Wanneria* is found in Nevada, in Alabama, and in Pennsylvania, thus showing that this genus is common to the Mississippian sea and to the long trough north-east of Alabama. *Mesonacis* has been obtained in the submarine depression at Lake Champlain, at Bonne Bay, Newfoundland, and at the north side of the Straits of Belle Isle. *Elliptocephalus* has been recorded from the New York State. *Olenellus* has been found in Nevada, in Vermont, and in the North-West Highlands. All the genera now referred to may have migrated along the north-western shore of this trough.

As regards the distribution of the genus *Callavia*, this form has been met with in Maine, in Newfoundland, and in derived pebbles in a conglomerate in Quebec. Two species have been recorded in Shropshire. These forms probably moved along the southern shore of this sea from Wales to North America.

Reference has already been made to the fact that, in the interval between Lower and Middle Cambrian time, in certain areas in North America, the Lower Cambrian rocks were locally elevated and subjected to erosion. During this interval the southern end of the trough seems to have had no connexion with the Mississippian sea, for in Middle Cambrian time, as already indicated, the *Paradoxides* fauna is found in the trough on the east side of North America, whereas on the west side it is represented by the *Olenoides* fauna.

In Upper Cambrian time a great transgression of the sea towards the north supervened. The *Dikelocephalus* fauna is found on both sides of America, thus showing that the previous land barrier had been submerged. While this genus occurs in Wales and the Baltic provinces, it has not as yet been recorded from the North-West Highlands, but I quite expect that this discovery may be made at some future time.

Along the northern side of the American trough clear-water conditions prevailed, owing to the northward recession of the shore-line, which led to the accumulation of a great succession of calcareous deposits, including the Beekmantown Limestone, to which reference has already been made. Schuchert, as already stated, has pointed out that, in the lower part of the Ozarkic (Upper Cambrian) System, in Minnesota and Wisconsin, the Gasteropod genera *Holopea, Ophileta,* and *Raphistoma* are associated with two species of *Dikelocephalus*. This molluscan fauna is evidently the precursor of that of the Beekmantown Limestone. It was probably from this central region of America that the calcareous fauna of Beekmantown migrated to the submarine trough in the typical Champlain region, and through Newfoundland to the North-West Highlands of Scotland.

The section at St. John, New Brunswick, where the Baltic and Welsh types of the *Olenus* fauna occur, shows that the southern shore-line of the trough must then have occupied much the same relative position as in Lower and Middle Cambrian time. In the same region the strata containing this fauna, with *Peltura scarabæoides* and *Dictyonema flabelliforme,* are overlain by dark shales with Arenig Graptolites. These Graptolite-bearing terrigenous deposits eventually extended across the trough northwards, till, in Newfoundland, they came to rest on the Beekmantown limestones.

In the Lake Champlain region, in the Chazy Limestone, which there immediately succeeds the Beekmantown Limestone without the intervention of the Arenig Graptolite shale, there is a survival of the Beekmantown molluscan fauna with only such slight modifications as to indicate genetic descent. In the same trough the descendants of this fauna are to be found in the Trenton Limestone.

In this connexion it is worthy of note that the molluscan fauna and the corals of the Stinchar and Craighead Limestones of Upper Llandeilo age in the Girvan district of the Southern Uplands have an American facies, as first suggested by Nicholson. The appearance of American types in these limestones may be accounted for in the following manner: Attention has already been called to the divergent types of sedimentation presented by the Upper Cambrian strata of the North-West Highlands and of the South-East Highlands, at Stonehaven and Aberfoyle. In the former case there is a continuous sequence of dolomites and limestones, while in the latter we find a group, comprising Radiolarian cherts and black shales, associated with pillowy spilitic lavas and intrusive igneous rocks, indicating conditions of deposition at or near the limit of sedimentation. But, notwithstanding the different types of sedimentation and the divergent faunas in the two areas, I believe that during the Upper Cambrian period, and probably for some time thereafter, continuous sea extended from the North-West Highlands to beyond the Eastern Highland border. The Upper Cambrian terrigenous sediments which we now find at Stonehaven and Aberfoyle must have been derived from land to the south. In Llandeilo time the Arenig and Lower Llandeilo rocks of the Girvan area were elevated and subjected to extensive denudation. On this highly eroded platform, as first proved by Professor Lapworth, coarse conglomerates, composed of the underlying materials, were laid down in association with the Stinchar and Craighead Limestones. In my opinion the appearance of the American forms in these limestones is connected with the movement that produced this unconformability in the Girvan area. This local elevation was probably associated in some form with the great crustal movements that culminated in the overthrusts of the North-West Highlands and caused the intense folding and flaser structure of the rocks along the Highland border. By these movements shore-lines may have been established between the north side of the old Palæozoic sea and the Girvan area, which permitted the southern migration of the American forms.

Note. Since writing the above my attention has been directed to the recent work of Bassler on *The Early Palæozoic Bryozoa of the Baltic*

Provinces, published by the Smithsonian Institution in 1911. In his introduction the author has shown that the Ordovician (Lower Silurian) and Gothlandian (Upper Silurian) rocks of the Baltic Provinces contain a large percentage of Bryozoan species, in common with the Black River, Trenton, and Niagara Limestones of the same relative age in Eastern North America. This fact suggests that during Lower and Upper Silurian time the old lines of migration were still open, and that the Bryozoa, being of clear-water habit, were able to cross the old trough from side to side.

III.—British Association for the Advancement of Science, Eighty-second Annual Meeting, held at Dundee, September 4–11, 1912. List of Titles of Papers read in Section C (Geology) and in other Sections bearing upon Geology.

Presidential Address by *Dr. Benjamin N. Peach, F.R.S.*

Professor Thomas J. Jehu.—Address on the Geology of the Country around Dundee and St. Andrews.

Mr. E. B. Bailey.—A Mull Problem: The Great Tertiary Breccia.

Mr. C. I. Gardiner.—On the Silurian Inlier of Usk.

Mr. T. O. Bosworth.—The Heavy Mineral Grains in the Sandstone of the Scottish Carboniferous.

The Rev. A. Irving.—Preliminary Note on a Buried River Channel near Peterborough.

Report of the Committee on the Composition and Origin of the Crystalline Rocks of Anglesey.

Report of the Committee on the Bembridge Limestone at Creechbarrow Hill.

Dr. Robert Campbell.—The Discovery of Fossils in the Jasper and Green Schist Series of the Highland Border at Craigevin Bay, Stonehaven.

Dr. Robert Campbell.—The Downtonian and Old Red Sandstone of Kincardineshire.

Dr. R. H. Traquair, F.R.S.—On *Cyathaspis* from the Downtonian Rocks of Stonehaven.

Professor T. J. Jehu.—Discovery of Fossils in the Boundary Fault Series near Aberfoyle.

Mr. Archibald W. R. Don.—On the Nature of *Parka decipiens.*

Mr. John H. Wilson.—Uncharted Volcanic Necks at St. Andrews.

Report of Committee on the *Index Animalium* (also in Section D, Zoology).

Dr. John S. Flett.—The Sequence of Volcanic Rocks in Scotland in relation to the Atlantic–Pacific Classification of Suess.

Mr. George Barrow.—The Older Granite in Lower Dee-side.

Mr. G. W. Tyrrell.—The Alkaline Igneous Rocks of Ayrshire.

Dr. William Mackie.—The Volcanic Rocks around the Ord Hill of Rhynie, Aberdeenshire.

Dr. A. W. Gibb.—On an Actinolite-bearing Rock associated with Serpentine.

Mr. Edward Greenly.—On the Origin of some of the Mica-schists of Anglesey.

Mr. Albert Gilligan.—The Millstone Grit of Yorkshire—New Evidence of its Source of Origin.

Mr. Albert Jowett.—Notes on the Volcanic Rocks and their Associated Sediments of the Forfarshire Coast between the Red Head and Montrose.
Dr. W. T. Gordon.—The Fossil Flora of the Pettycur Limestone in relation to Botanical Evolution.
Dr. Marie C. Stopes.—Palæobotany *versus* Stratigraphy in New Brunswick.
Dr. B. N. Peach, F.R.S., & Dr. J. Horne, F.R.S.—The Archæan Rocks of the Island of Lewis.
Dr. J. S. Owens.—The Settlement and Transport of Sand in Water.
Mr. George Barrow.—On Buckled Folding.
Mr. Edward Greenly.—A Theory of the Menai Strait.
Mr. J. D. Falconer.—On the Origin of 'Kopjes' and 'Inselberge'.
Mr. G. W. Grabham.—Note on the Country North of Lake Albert.
Dr. J. W. Spencer.—Post-Glacial Changes of Level *versus* Recent Stability of the Lake Region of North America.
Mr. A. R. Horwood.—On a Fossiliferous Tufa occurring beneath Chalky Boulder-clay at Launde, Leicestershire.

Section A.—Mathematical and Physical.

Dr. J. Milne, F.R.S.—Report on Seismological Investigations.

Section E.—Geography.

Presidential Address by *Colonel Sir Charles M. Watson, K.C.M.G.*
Colonel C. F. Close.—The International Map.
Mr. E. A. Reeves.—Recent Improvements in Surveying Instruments.
Dr. H. M. Ami.—Geographical Progress in Canada.
Sir H. G. Fordham.—Notes on British and Irish Itineraries and Road Books.
Sir Clements Markham.—Antarctic Discovery.
Dr. F. Oswald.—From the Victoria Nyanza to the Kisii Highlands.
Mr. H. M. Cadell.—The Development of some Scottish Rivers.
Mr. A. H. Garstang, F.R.S.—Some Canons of the Cevennes.
Dr. J. W. Spencer.—Submarine Canon of the Hudson River.
Dr. W. S. Bruce.—The Antarctic Continent.
Mr. E. A. Martin.—Dew-Ponds and Mist-Ponds.

IV.—Index Generum et Specierum Animalium.[1]

Final Report of the Committee, consisting of Dr. Henry Woodward (Chairman), Dr. F. A. Bather (Secretary), Dr. W. T. Calman, Dr. W. Evans Hoyle, the Hon. Walter Rothschild, Dr. P. L. Sclater, the Rev. T. R. R. Stebbing, and Lord Walsingham.

During the year 1911–12 work on this *Index* has proceeded steadily, and a large number of volumes has passed through the hands of Mr. C. Davies Sherborn.

Huebner's entomological works have been thoroughly examined, and the results of the researches of many workers have been embodied in a paper by Sherborn & Prout in the *Annals and Magazine of Natural History* for January, 1912. All the books of Fallén and Fabricius have been indexed, as also those of Fischer von Waldheim and John Fleming.

[1] Read before the British Association, Sections C (Geology) and D (Zoology), Dundee, September, 1912.

with many others. Increased cabinet accommodation has been necessary, and this has been, as before, provided at the Natural History Museum by the Keeper of the Geological Department.

As regards the continuation of the work, the Committee has great pleasure in reporting that the Trustees of the British Museum have included the compilation of the *Index Animalium* in the General Library Service of the British Museum (Natural History). It has thus become an official undertaking, and Mr. Sherborn will rank as 'Special Assistant' on the staff. This is most gratifying to all parties concerned, for it ensures the safety and completion of the manuscripts which have accumulated during the past twenty-two years. There are now some 664,000 slips, representing 332,000 entries in duplicate, and a great mass of manuscript notes on the dates of books which have passed or will pass through the compiler's hands. Much of this has been printed separately or been included in the official catalogue of the libraries of the British Museum (Natural History).

All manuscripts and documents connected with the work have been handed over by the Committee to the Trustees of the British Museum for preservation in the Natural History Museum, where they may be seen, on application during official hours, by those interested.

In making this final report the Committee desires to express its own and Mr. Sherborn's sincere thanks, not only to the Trustees of the British Museum for their past and present help but also to those Societies that have from time to time aided the work with pecuniary grants—namely, the Royal Society and the Zoological Society of London. Above all, those thanks are due to the British Association for the consistent way in which it has supported the undertaking for the past twenty years, support which alone made possible the successful termination of the first part (1758–1800). The Association will doubtless join the Committee in renewing its thanks to the Syndics of the Cambridge University Press for their generosity in printing and publishing this part. It was issued in October, 1902, as a handsome octavo volume of 1,255 pages, containing 61,600 entries, at the price of 25*s*. On the value of that volume to the zoologist there is no need to insist here; it has spoken for itself to everyone who has taken the trouble to consult it. The manuscript of the second part (1801–50) is well advanced, and will now proceed safely towards completion under new auspices.

Your Committee cannot cease its connexion with this important work without an expression of gratitude to Mr. Davies Sherborn for his devoted labours in the past, and of confidence in his energy to carry to a conclusion the second part of the *Index Animalium*.

V.—PALÆOBOTANY *VERSUS* STRATIGRAPHY IN NEW BRUNSWICK.[1] By MARIE C. STOPES, D.Sc., Ph.D., F.L.S.

OUTLINE of the controversy, which dates from 1866. The so-called 'Fern Ledges' near St. John, New Brunswick, have a rich fossil flora, but almost no animal remains. Sir W. Dawson described the plants as Devonian. Confusion still exists owing to the mixture of true Devonian plants from Gaspé, etc., in the same monograph of Dawson's. Recent attempts include the beds in the Silurian, for 'stratigraphic' reasons. The necessity of field work as well as palæontological determinations. The author's work in the field; notes on relative dips of the beds, the so-called 'slates', intrusive rocks, and contortions. Observations indicate existence of considerable overthrust. Palæobotanical data. Re-determination of supposed 'unique' species. Type-specimens lent by the Canadian museums and brought to London

[1] Abstract of papers read before the British Association, Section C (Geology), Dundee, September, 1912.

and Paris for comparison with standard collections, resulting in identification of a large proportion of well-known European types in the 'Fern Ledges' flora, all Carboniferous and mostly typical of Westphalian division in Coal-measures. Note the value of fossil plants, as the Carboniferous age of the beds was recognized by Geinitz in 1866 from a single specimen of a fern leaf. The author did the work for the Canadian Geological Survey, to the kindness of whose Director is due the permission to give this résumé of the results.

VI.—The Fossil Flora of the Pettycur Limestone in relation to Botanical Evolution.[1] By W. T. Gordon, M.A., B.A., D.Sc.

THE oldest flora of which we have considerable knowledge is that represented in Upper Devonian rocks, but the plants obtained from Lower Carboniferous strata do not differ markedly from the Devonian types, and so may be included in the Devonian flora. Examples of petrified plants of Lower Carboniferous age have been recorded from several localities in Scotland, but they are nowhere so abundant as at Pettycur, near Kinghorn, Fife. The flora of the Pettycur Limestone, then, has a double interest; the remains constitute fragments of the oldest known flora, and, as they are petrified, the internal structure of these plants may be studied.

Although the Devonian flora is very distinct from that of the succeeding Permo-Carboniferous epoch, yet the organization does not indicate that the plants were primitive. Indeed, all one can say is that the assemblage, as a whole, appears to be less highly specialized than that represented in Upper Carboniferous strata.

As the horizon of the Pettycur rocks is rather high in the Calciferous Sandstone Series, we would expect to find some species whose structure indicated a transition between Devonian and Upper Carboniferous forms. In some cases I believe that such specimens have been discovered. For example, we find several genera belonging to one order, or several species to the one genus, and in such cases one form is more generalized in structure than the others, while the less generalized forms appear to be more closely allied to Upper Carboniferous types.

Among the *Lepidodendra,* for instance, *Lepidodendron Pettycurense,* Kidston, has a perfectly solid central axis; the xylem cylinder in *Lepidophloios Scottii,* Gordon, is occasionally solid in places, but at other parts of the same specimen a mixed pith, consisting of parenchyma and short tracheides, may be noted. *Lepidodendron Veltheimianum,* Sternb., on the other hand, has a well-marked parenchymatous pith containing no tracheides. A line of development is thus suggested by this series, and when we turn to the Coal-measure flora a parallel series may be shown. The lowest member among the Upper Carboniferous *Lepidodendra* has a mixed pith, and hence we conclude that the Pettycur plants show less specialization than those of a later date, though the organization is similar in each case. Such parallel series may also be demonstrated in other groups, particularly among the ferns and Pteridosperms.

The various reproductive members met with at Pettycur also exhibit certain peculiarities. The most complex cryptogamic cone yet discovered—*Cheirostrobus Pettycurensis,* Scott—was recorded from this locality. Certain characteristics common to several groups are combined in the cone, which is thus both complex and generalized.

In the megaspore of *Lepidodendron Veltheimianum,* Sternb., the archegonium has been recorded, and it does not differ from that of the living *Selaginella* or *Isoëtes.*

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

To sum up, then, the flora represented in the Pettycur Limestone appears, on the whole, to contain more generalized and simpler types than occur in the Coal-measure and later strata, and these types may be arranged in order so as to suggest certain possible lines of evolution.

VII.—On the Nature of *Parka decipiens*.[1] By Archibald W. R. Don, B.A.

THIS paper was the outcome of an attempted re-investigation of *Parka*, chiefly microscopical, with the aid of Schultz's solution (strong nitric acid and potassium chlorate). Being the only common and quite the most characteristic fossil of the Lower Old Red Sandstone of the Kincardine-Forfar-Perth area, it has naturally attracted considerable attention. The nature of *Parka* has been a subject of speculation ever since its discovery at Parkhill in 1831 by Dr. Fleming. He described it as probably allied to *Juncus* or *Sparganium*, and Hugh Miller, on the whole, agreed as to its vegetable nature. Mantell stoutly maintained it to be 'batrachian eggs'. Lyell thought it the egg-packet of *Pterygotus*, and this determination was accepted by Salter, Woodward, Powrie, and others. In 1890, however, Messrs. Reid, Graham, and Macnair, having convinced themselves of its vegetable nature, sent specimens to Sir W. Dawson, who, with Professor Penhallow, submitted it to a microscopical examination. They clearly showed it to be vegetable, and after boiling it in nitric acid, demonstrated the presence of spores within the carbonized tissue.

The conclusions, other than this main one, arrived at by former investigators have not as yet been confirmed by the present re-examination, the chief results of which, therefore, tend unfortunately to be more destructive than constructive. Hitherto no evidence for heterospory has appeared. The 'prothalli' have not been found. The mode of attachment and other vegetative features have not been elucidated, and an agnostic attitude is assumed, pending further discoveries, with regard to those formerly attributed to *Parka*. No evidence has appeared with regard to the supposed varieties '*media*' and '*minor*'. An attempt, admittedly tentative, has been made to form some conception of the original structure and shape of *Parka*, based on examination of certain excellently preserved impressions of its two surfaces. The main conclusion is that the original spore-containing tissue was almost flat, not spherical (and made up of numerous adjacent lens-shaped spore-sacs) —a structure, in fact, in no way comparable to anything Hydropteridian, and unlike any known sporangia of to-day. There was, certainly, intimately connected with it a so-called 'indusium'. Such a reconstruction must, however, be understood to be hypothetical, and not an ascertained fact. Certain cell-layers and tissues revealed by the more gentle action of the Schultz's solution may, however, help towards an ultimate solution of the perennial problem of *Parka decipiens*.

VIII.—Discovery of Fossils in the Boundary Fault Series, near Aberfoyle.[1] By T. J. Jehu, M.A., M.D.

THIS Series is well exposed between Loch Lomond and Callander, forming a narrow belt separated by a reversed fault from the Lower Old Red Sandstone on the south-east, and probably by a line of thrust from the Leny Grits on the north-west. It consists of black and grey shales, cherts, grits, and calcareous beds, with which are associated some altered igneous rocks. Adjoining the crushed and veined rock which runs along the boundary of the Lower Old Red Sandstone, patches of sheared serpentine are seen at several places, sometimes

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

associated with a coarse basic igneous rock somewhat brecciated, as at Maol Ruadh. These probably represent igneous intrusions. Near Loch Lomond grits only are exposed. At the north-east end, near Callander, the belt consists largely of grits, but at Kilmahog quarry there is a good exposure of black shales with an interbedded limestone identical in character with the limestone in the Margie Series described by Mr. G. Barrow (Q.J.G.S., 1901).

The belt in the Aberfoyle area emerges from under the Upper Old Red Sandstone north of Gualann and extends north-eastwards to a mile north-east of Aberfoyle. Widest near Gualann—about half a mile. General strike of beds north-east and south-west; general dip north-west, at high angles. Beds often isoclinally folded along crush-planes striking north-east and south-west. Apparent order of succession from below upwards near Kelty Water: (1) Hornblendic and chloritic schists, probably representing intrusive sheets; (2) thin band of chert and black shale, only traceable for about a mile; (3) band of grit which as traced to north-east comes to abut against Lower Old Red crush rock; (4) thicker band of black shales and cherts; (5) Grit. The Leny Grit follows on the north-west, but at other places it appears to come directly on the black shales and cherts.

Difficulty in distinguishing the grits of the Boundary Fault Series from the Leny Grits. The latter are generally greenish, the former greyish and weathering yellowish-brown, and are peculiar in containing fragments of black shale, chert, and vesicular volcanic matter. Lumps and courses of a very dark grit also occur in the black shales. The shales are usually black, carbonaceous, staining the fingers; generally very crushed. The cherts are pale grey to dark in colour, often finely banded with frequent interleaves of black shale. Joints and veins at right angles to the bedding often numerous. Thin cherty bands and nodules often seen in the shales. Some of the rocks are a crushed mass of black shale and cherty material. The beds are often distinctly brecciated.

Remains of Radiolaria discovered by Dr. Peach some years ago in cherts near Gualann. Recently a number of fossils have been found in pale-grey chert bands, 1 to 3 inches thick, in an exposure on the south-east side of the Bofrishlie Burn, about 400 yards north-west of Arndrum. The fossils occur in muddy films in the chert. Belt here only 300 to 350 feet wide. Some of the shales and cherts are thrust over the disrupted edges of the bands which have yielded fossils. A little north-west the cherts are brecciated, and courses of grit occur in the black shales, also showing signs of brecciation. Some calcareous bands occur in the shales in the bed of the stream. The fossils are almost all hingeless Brachiopods, and the following forms have been determined by Dr. Peach:—

Acrotreta sp., *Lingulella* sp., ? *Obolus* sp., *Obolella* sp., also the flattened chetæ of Polychæte worms.

The fossils indicate that the series is probably of Upper Cambrian age.

IX.—On the Origin of some of the Mica-schists of Anglesey.[1] By Edward Greenly.

In the south-east and centre of Anglesey extensive tracts of country are occupied by mica-schists in which it is a very rare thing to find any survival of the original structures. They are holocrystalline rocks, usually with strong parallel structure, and composed essentially of quartz, alkali-felspars, and a white mica. In certain compact varieties, however, especially about Y Graig, Holland Arms, traces of felsitic texture can be found. Dr. Teall, who has examined the rocks in the field as well as under the microscope, regards them as in all

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

probability broken down and partially reconstructed porphyritic felsites, and considers that some lenticular aggregates which they contain may be looked upon as broken-down porphyritic felspars. Twenty-five years ago Dr. Callaway recognized the felsitic origin of these rocks, and the present investigations fully confirm that conclusion.[1] Similar structures have now been found in the rocks of the central area, on its western coast near Trecastell. These schists, therefore, may be looked upon in general as derived from acid igneous rocks. In other parts of both areas, however, mica-schists in continuity with them are found in intimate relations to schists of sedimentary origin, so that it is probable that pyroclastic material was present in the original igneous series.

X.—The Older Granite in Lower Dee-side.[2] By G. Barrow, F.G.S.

A BRIEF description was given of the mode of occurrence and composition of one of the older Granite intrusions in Lower Dee-side. In place of forming large coherent masses it tends rather to minute subdivision, permeating the crystalline gneisses over large areas. Excellent examples of *lit-par-lit* intrusion may be seen on the north side of the Dee, about, and west of, Banchory. The granitic material in these cases forms minute sills, varying from an inch to several feet thick, and almost rigidly parallel to the foliation of the associated gneiss into which it has been intruded. The ground here is comparatively flat, and the method of feeding the sills cannot be clearly made out. But on the opposite or south side of the river the ground is much steeper, and in the hill-faces dyke-like intrusions can be seen, from which the sills proceed. They commence a little below the crest of the dyke, where they are smallest and shortest; they are seen to become steadily thicker and longer as we descend further below the crest of the dyke. In the interior of the latter the granite is usually grey, and contains more biotite than muscovite; oligoclase is also usually abundant; the oligoclase and biotite steadily diminish in amount as the rock is traced towards the taper end of the sills. At this point there is little oligoclase, and often no biotite; muscovite is fairly common, often in large crystals, and the bulk of the felspar is of alkaline composition. It appears that the fissures in which the dykes occur were filled with igneous material, and that under great pressure the walls were burst open and the still liquid material forced out, and thus separated from that which had already segregated out. The phenomenon may be described as magmatic differentiation intensified by dynamic action. Further, the material (pegmatite) which occurs on the extreme ends of the sills is often far coarser than that met with in the centre of the dyke; the distribution of coarse and fine material being thus the reverse of that usually met with in small intrusions.

This separation of the more acid and less acid material occurs in connexion with every dyke and sill over the entire Dee-side area between Banchory and Aberdeen; the pegmatitic material forming a fringing margin, the breadth of which varies considerably. The largest of the sill-like masses occurs at Aberdeen, and part of the city is built on it; its great fringe of pegmatite veins is well displayed on the banks of the Dee near the railway bridge.

The separation of the material rich in oligoclase and biotite from that richer in alkali-felspar and muscovite is not confined to each separate intrusion; it holds good for the intrusion as a whole. Well to the south of the Dee, especially nearer the coast, nearly the whole of the intrusions are more alkaline than those nearer the Dee; the

[1] See Brit. Assoc. Report, Manchester, 1887; also Q.J.G.S., 1897 and 1902.

[2] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

pegmatite remains of much the same composition, but there is a considerable amount of schorl present in the southern area that is distinctly rare in the northern.

There is considerable variation in the amount of foliation shown by these intrusions. In the moderate-sized or larger ones the centre is usually unfoliated, or but slightly so; towards the margins the foliation is more marked. The pegmatite fringe is rarely foliated if it occurs as veins or dykes; but it usually is more or less foliated if in thin sills. The foliation over most of the area is protoplastic; post-consolidation crushing is rare. Indeed, it is only well seen in one case, where the granite has reached the present surface far south of the main series of intrusions, and within a lower temperature zone. This intrusion is cut open by a branch of the Cowie Water, close to the Stonehaven Road from Banchory.

XI.—On a Fossiliferous Tufa occurring beneath Chalky Boulder-clay at Launde, Leicestershire.[1] By A. R. Horwood.

In the Report on Erratic Blocks of the British Isles, presented at the Winnipeg Meeting, 1909 (Report B.A., 1909, p. 176), I mentioned the occurrence of a large boulder of tufa found by the side of a stream, the River Chater, at Launde, Leicestershire. At the time I had no doubt the rock was an erratic.

Since then Mr. A. J. S. Cannon has brought me a specimen of the same rock containing land-shells, which he informed me he had found in situ in the same locality. Recognizing the importance of this discovery I accompanied him later to examine the section, with the result that this rock was found in two different places a quarter of a mile apart.

At the first point a section is exposed in the stream-side as follows:—

	ft.	in.
1. Soil	0	6
2. Chalky Boulder-clay, sand and gravel, with Jurassic fossils	*c.* 2	0
3. Calcareous tufa, with plants and land-shells, also *Pisidium*, Entomostraca	0	6
4. Peat, with plant-remains and shells	1	0
5. Tufa, similar to 3	0	6
6. Inclined *margaritatus* shales (Middle Lias)	3	0
	7	6

The disturbed character of the basal beds has no connexion with beds 1 to 5, which are clearly undisturbed, and have not been inverted or thrown out of position since they were deposited.

The importance of this section is evident, for with the exception of a deposit containing plants, Annelids, Crustacea, and Mollusca at Aylestone in the Soar Valley in Holocene deposits, and a similar fauna at Medbourne in the Welland Valley (not yet described), the Launde section is the only ancient one so far discovered in Leicestershire.

In the same district at Launde the tufa was found exposed in ditch-bottoms and rabbit-holes under superficial deposits, some 2,000 feet away. The nearest sections of the same or later age are in Rutland at Apethorp, near Stamford, and at Casewick. I have been favoured by Mr. A. S. Kennard with specimens of the shells collected by J. F. Bentley at Stamford, and described by Professor T. R. Jones, and there is a close similarity between such species as *Helix rotundata, Vitrea radiatula,* and *Carychium minimum,* which are the dominant shells at Launde. There are more than twenty species of land and fresh-water shells, besides plants, that remain to be examined. No mammalian remains have been found, nor evidence of the activity of man in this locality.

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

XII.—The Discovery of Fossils in the Jasper and Green Schist Series of the Highland Border at Craigeven Bay, Stonehaven. By Robert Campbell, M.A., D.Sc.

BETWEEN Craigeven Bay and Garron Point occurs a series of crushed spilitic lavas with intercalated black shales, jaspers, and cherts. In their lithological characters these resemble closely the green igneous rocks and associated sediments which appear at intervals along the line of the Highland Boundary fault, and which are shown on the Geological Survey maps as of (?) Arenig age. In August, 1909, on the occasion of a visit to Craigeven Bay in company with Dr. B. N. Peach and Dr. W. T. Gordon, we succeeded in finding in the black shales several fossils, including a linguloid shell and a bivalve Phyllocarid Crustacean. The assistance of Mr. D. Tait, of H.M. Geological Survey, was obtained in making a detailed search in the fossiliferous beds. Dr. Peach, to whom the fossils were submitted for determination, has identified the following forms: *Lingulella, Obolella, Acrotreta, Linnarssonia,* and *Siphonotreta*; a bivalve Phyllocarid allied to *Caryocaris* and *Lingulocaris*; and cases of a tubicolar worm. The above genera are most commonly found in the lowest division of the Lower Silurian (Ordovician) system and in the Upper Cambrian. Dr. Peach, while admitting that the exact horizon of the fossils is still a matter of doubt, suggests that, since Graptolites are absent, they are more likely to belong to the Upper Cambrian than to the Ordovician. Whatever may be the ultimate decision as to their stratigraphical horizon the discovery of the above fossils leaves very little doubt that the boundary fault series is *not* pre-Cambrian.

The (?) Upper Cambrian rocks at Craigeven Bay are separated from the Dalradian Schists by a reversed fault, and are overlain unconformably by Upper Silurian (Downtonian) strata.

REVIEWS.

I.—Monograph on the Sub-oceanic Physiography of the North Atlantic Ocean. By Edward Hull, M.A., LL.D., F.R.S. With a chapter on the Sub-oceanic Physical Features off the coast of North America and the West Indian Islands. By Professor Joseph W. W. Spencer, M.A., Ph.D. Folio (18 by 12½ inches); pp. viii, 42, with 11 maps (9 coloured). London: Edward Stanford, Long Acre, W.C., 1912. Price 21*s.* net (post free in United Kingdom 21*s.* 7*d.*).

IN Professor Hull's Atlas of Maps with its accompanying text we have a summary of the author's long-continued observations and deductions concerning the eastern coast of the North Atlantic, and his work is supplemented by that of his friend Professor J. W. Spencer on the Atlantic coast of North America and the West Indian Islands. It brings before the student a collection of facts on submarine coastal features which, if not all new to us, are so ably put forward that they cannot fail to attract the attention of a large class of persons interested in the cartography of the British Islands, especially in their relation to neighbouring lands, of which, at no distant period, they formed a solid part.

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

In this atlas Professor Hull gives us a view of those submarine foundations of Britain, stretching out over a wide area around our shores, which were almost certainly dry land, during Pleistocene or early prehistoric times, when these Islands (then continental areas) were inhabited by Palæolithic man and largely covered by forests and vast grassy plains, the home of the mammoth and rhinoceros, its rivers and lakes frequented by the hippopotamus, its pampas-like plains affording abundant pasturage for countless wild horses, herds of red deer and reindeer, bison and elks, which were free to migrate with the seasons, and rove by dry land from Anglia over the continent, from Yorkshire to Brittany, and to cross the valley of the Irish Sea into the then *United* Ireland also; whilst the *Machairodus*, the cave-lion, wolves, bears, and hyænas battened upon the herbivora, and contended with early man for possession of the warmest caves and rock-shelters.

But we are digressing, for the author does not treat of the fauna and flora, but devotes himself specially to the physical features of the then dry land which now forms the 'continental shelf' whereon our Islands rest, and which once was no mean part of Britannia's *dry land*—drained on the west by the Irish River Channel, on the south by the English Channel River, while numerous continental rivers, as the Rhine, the Weser, the Elbe, flowed north, and the Seine, the Loire, Gironde, Adour, and our own Thames all reached the edge of the continental platform far to the south.

Plate i presents us with an outline, on a small scale, of the British Islands and adjacent seas, showing the limits of the continental platform where shallow soundings end and deep water sets in, the margin descending from 200 to 500, to 750, and 1,000 fathoms, or over a mile in depth.

Plate ii on a double page is an orographical map of the British Isles with isobathic contours, and showing the courses of the submerged river valleys as far as the author has been able to trace them by the aid of the soundings furnished by the Admiralty Charts.

Plate iii gives the coast of the English Channel and the Bay of Biscay with all the soundings as shown on the charts and the lower border of the continental platform along the French and English coasts. On this subject it will be remembered that Godwin-Austen brought before the Geological Society an elaborate paper (published in 1850) on the valley of the English Channel, illustrated by a chart.

Plate iv, which is a two-page size map, shows the west coast of Spain and Portugal, the soundings being added.

Plate v, another two-page map, gives the western Mediterranean coasts, Spain, France, and Italy, with Corsica and Sardinia, Sicily, etc., and the submerged land platforms around them like our own Islands.

Plate vi shows the west coast of Africa, and the submerged valley of the Congo extending for 122 miles to the westward.

Plate vii gives us the British Islands during the Lower Glacial epoch, all submerged except the small areas of highlands and the southern portion, together with the narrow chalk barrier between the Straits of Dover then still existing.

Plate viii introduces a map of Norway and its grand series of fjords, some of which show soundings of 5,000 to 6,000 feet in the central part. That the coasts of Norway have in geological times stood at a very much higher level than at present is shown by the submerged lines and groovings of glacial erosion, which can be traced on the sides of its fjords. There is also evidence of old sea beaches, now greatly *above* the reach of tides, attesting a subsequent re-elevation of the land in later times.

Plate ix shows the physical conditions of the Northern Hemisphere in the Glacial period.

Plate x takes us, under the guidance of Professor J. W. Spencer, to a survey of the submarine valleys along the American coast and thence to the Gulf of Mexico and the submerged valleys and fjords of the West Indies.

In plate xi we are introduced to the submerged valleys of the Arctic basin and Greenland.

In dealing with the mode of formation of the continental platform and accompanying shelf, we have to recognize that the land of the Northern Hemisphere has undergone enormous changes of level in Pliocene and Pleistocene times—changes of elevation and depression and of elevation again; this, in the opinion of the authors, can be abundantly proved by a consideration of the phenomena of the submerged river valleys.

The floor of the shelf was at one time a land surface, as shown by the river channels by which it is traversed, which could never have been carved under the waters of the ocean itself, and the continental slope constituted the coastline of the ocean at various stages of elevation and depression. During this process of terrestrial movement there were doubtless pauses when the surface of the platform was swept by the Atlantic waves; and the continental shelf was the outcome mainly of wave-action and erosion on the one hand, and the action of atmospheric denudation on the other, where the rains, rills, and streams have reduced the coastal plains to levels of no erosion; in either case submerged terraces or platforms result upon the sinking of the land or rise of the ocean level. The continental slope, formed to some extent of terraces hewn out of the rock, as the land rose or fell, assumed its present form somewhat as do the now emergent cliffs on the rock-bound coasts of Norway, Scotland, and Ireland. Such in general terms, writes Professor Hull, appears to have been the process by which the submerged features were formed. It involves a recognition of a great lapse of time, which is difficult for the mind to realize, especially at so recent a stage of the world's history; nevertheless, the evidence appears conclusive that, given the necessary time, these great terrestrial results have been accomplished mainly by wave-action on the lands during periods of elevation and depression, accompanied by occasional pauses giving rise to terraces (p. 5).

Space does not permit us to give a fuller notice of this important work, which furnishes much information beyond the actual scope of the title, although bearing upon the same subject. I recall a MS. map by my father which must have dated back to 1825 or earlier, showing the continental platform and proving how far back the attention of geologists had been drawn to the former connexion of the British

Islands with the continent as proved by the old Admiralty Charts, and the personal knowledge of the coasts gathered by Samuel Woodward, of Norwich, from the fishermen of the North Sea and the captains of ships along the coast. But there is much concerning this subject which has been added to our knowledge in the past 100 years, and such maps as are now produced were unknown in those days. Thus, in the little map published by De la Beche (*Researches in Theoretical Geology*, 1834, p. 190), he showed that "if the British Islands were elevated one hundred fathoms above the level of the ocean, and thus joined to the continent of Europe, they would be surrounded by an extensive area of flat land"; but he then stated (p. 189) that "the soundings round coasts present us with no lines which we might consider to be those of valleys".

H. W.

II.—Maryland Geological Survey.

We have received a copy of vol. ix, dated 1911, of the general reports of this Survey, comprising the third and fourth (final) and summary final reports on State Highway Construction. During a period of twelve years the total road expenditures under the auspices of the State Geological Survey have amounted to more than one and three-quarter million dollars: the work is now carried on under the State Roads Commission. The same volume contains a "Report on the Iron Ores of Maryland", by Mr. J. T. Singewald, jun. The ores consist of magnetite, hematite, limonite (including bog iron ores), and siderite; and the author describes their geological position, extent, and origin. He also gives a history of the Maryland iron industry, with descriptions of the various iron works. The report is well illustrated with maps and photographic views.

Another volume, of 622 pages with 97 plates and 15 text-illustrations, is entitled "Lower Cretaceous", being the fourth of a series dealing with the systematic geology and palæontology of Maryland. The preceding volumes were on the Tertiary and Quaternary deposits. In the present great work the main geological and palæontological features of the Lower Cretaceous are described by Dr. W. Bullock Clark (State Geologist), Mr. A. B. Bibbins, and Mr. E. W. Berry. The system consists of the Potomac Group, which is divided (in ascending order) into the Patuxent, Arundel, and Patapsco Formations. Mr. Berry contributes an account of the Lower Cretaceous Floras of the World and of the Correlation of the Potomac Formations; he also describes the many species of Maryland fossil plants. The fossil vertebrata are dealt with by Mr. R. S. Lull, and the mollusca, which include only *Bythinia*, *Viviparus*, *Cyrena*, and *Unio*, are described by Dr. Clark.

We have further received a memoir on "The Physical Features of Prince George's County", in which the physiography, geology, mineral resources, soils, climate, hydrography, and forests are described. The rocks include small areas of crystalline rocks, gneiss, serpentine, gabbro, and diorite, possibly of Archæan age. The main areas are of Cretaceous, Eocene, Miocene, Pliocene (?), and later deposits. Good illustrations are given of characteristic fossils, and there are instructive views of scenery and geological formations.

III.—Virginia Geological Survey.

BULLETIN No. IV, 1912, consists of a description of "The Physiography and Geology of the Coastal Plain Province of Virginia", by Dr. W. Bullock Clark and Mr. B. Le Roy Miller; with chapters on the Lower Cretaceous, by Mr. E. W. Berry, and on the Economic Geology, by Dr. T. L. Watson, Director of the Survey.

The Coastal Plain, which is bordered by Pre-Cambrian crystalline rocks and by Cambrian, Ordovician, Triassic, and Lower Cretaceous strata, consists mainly of a series of dissected terraces. These are made up of Eocene and Miocene sands, clays, and marls, and of Pleistocene and Recent deposits of sand, clay, peat, and gravel. Particulars are given of the strata and of the geological events which they indicate, the subject being well illustrated by photographic plates and a good colour-printed map. The economic deposits consist mainly of clays; there are also marls, used as natural fertilizers and in the manufacture of cement. A deposit of diatomaceous earth, known as the "Richmond earth", is 30 feet thick in places, and is exposed along the numerous streams close to their crossings from the crystalline rocks on to the sediments of the Coastal Plain. The region in general is an agricultural one with a great variety of soil types, and it is recognized as important "to study in great detail the stratigraphy of the various formations, in order fully to interpret the soils".

IV.—Regional Geology.

THE excellent idea of Professors Steinmann and Wilchens to publish a *Handbuch der Regional Geologie*, which should be issued in separate parts so that geologists can purchase the district they require, is proceeding satisfactorily. Already ten parts have been issued as follows: Denmark, by Ussing (1m. 60); Spain, by R. Douvillé (8m.); Iceland, by Pieturss (1m. 20); Armenia, by Oswald (2m. 80); Persia, by Stahl (2m. 80); Philippines, by Smith (1m. 20); New Zealand, by Marshall (3m. 50); Oceania, by Marshall (1m. 60); Madagascar, by Lemoine (2m. 10); Mid-Atlantic Volcanic Islands, by Gagel (1m. 40). Each part is complete in itself, has maps and sections, gives a full summary of the geology of the area dealt with, and a bibliography. Regional Geology is published in large octavo form by Carl Winter, of Heidelberg, and should prove extremely useful to geologists. The method of publication in areas allows of fresh issues from time to time, each extending and revising the matter dealt with.

V.—Fossil Angiosperms.

Earliest European Angiosperms.—While preparing a catalogue of the Cretaceous plants in the British Museum, Dr. Marie C. Stopes came across three specimens of petrified wood which prove that higher woody Angiosperms existed in this country in Aptian times. These specimens are described in her paper in the Philosophical Transactions of the Royal Society (ser. B, vol. 203, pp. 75–100, pls. vi–viii, 1912), the objects of which are to record the evidence of this important find, to describe botanically the anatomy of the specimens, which belong to three new genera, and to note their points of structural and phylogenetic interest. Two of the specimens came from the Lower Greensand of Woburn Sands, Bedfordshire, the third from the same formation of probably Luccomb Chine, Isle of Wight; and they are referred to three new genera and species, *Aptiana radiata*, *Woburnia porosa*, and *Sabulia scottii*. These woods show no resemblance to any group of the Gymnosperms, but appear to be like highly-placed Angiosperms; however, no very definite statement can be made as to their affinities, so Dr. Stopes refrains from entering into an elaborate discussion on their bearing on the origin of the Angiosperms. Hitherto it was thought that the Angiosperms in Lower Cretaceous times had not spread eastward farther than Portugal, and the chief interest in the present specimens is their occurrence in Northern Europe in Aptian times.

VI.—Analysis of a Peruvian Lake.

Lake Parinacochas.—Particulars of the composition of the water of this lake have been published by Messrs. G. S. Jamieson and Hiram Bingham (*Amer. Journ. Sci.*, July, 1912, p. 12). Lake Parinacochas is situated in Peru, between 15° and 16° S. latitude and 73° and 74° longitude W. of Greenwich. It is about 150 miles north-west of Arequipa, and about 170 miles south-west of Cuzco. It is fed by small streams, and when visited in 1911 it had no visible outlet. Its elevation is about 11,500 feet above sea-level; its length was about 18 miles, the width 7 miles, and the depth almost uniformly 4½ feet in November, 1911. The composition of the water in milligrams per litre is stated as follows:—

Sodium chloride	9,324·0
,, sulphate	649·3
,, borate	212·4
Potassium sulphate	965·6
,, nitrate	78·0
Calcium sulphate	435·8
,, carbonate	33·8
Magnesium carbonate	342·8
Ferric phosphate	9·3
Silica	8·0
	12,059·0

The salinity is about one-third that of the Atlantic Ocean, and about one-twentieth that of the Great Salt Lake.

VII.—Lower Huronian Fossils.

Canadian Fossils.—Some fossils from the Steeprock Series (Lower Huronian) of Steeprock Lake, north-west of Atikokan, Ontario, have been studied by Dr. Charles D. Walcott, who considers them to be forms related to the Porifera and possessing characters also of the Archæocyathinæ. On this new material the genus *Atikokania* is founded, and two species, *lawsoni* (the genotype) and *irregularis*, are described. The central cavity and radiating tubes of *A. lawsoni* resemble Griffith Taylor's genus *Syringocnema*, and the tube walls of the former seem also to be perforate. The new genus is distinguished from *Syringocnema* by the presence of irregular septa, and so can be compared with *Pycnoidocyathus* and *Spirocyathus* of Taylor; its mode of growth seems to be essentially the same as that of the Archæocyathinæ. These specimens are described and figured in "Notes on Fossils from Limestone of Steeprock Lake, Ontario" (Appendix to Memoir No. 28, Geol. Survey Canada, 1912).

VIII.—Brief Notices.

1. Meteoric Stone from Kansas.—A second meteoric stone has been found in Scott County, Kansas, and this forms the subject of a paper by Dr. George P. Merrill (Proc. U.S. National Museum, No. 1905, vol. xlii, pp. 295–6, with pl. xxxix, 1912). It is a wedge-shaped fragment weighing 1,900 grams, and it has a fracture so recent that it is scarcely coated by a fused crust. The specimen, which is to be known as the Scott City stone, is chondritic, and the microscopic chondrules are of the usual olivine-pyroxene type, but nothing that could be with certainty identified as a felspar was observed.

2. Waverlyan Period of Tennessee.—The formations that are grouped under this period are in ascending order the Chattanooga, Kinderhookian, and Osagian, and they belong to the lower part of the sub-Carboniferous or Mississippian strata. The palæontological and stratigraphical relations of the formations are discussed by Mr. Ray S. Bassler (Proc. U.S. Nat. Mus., xli, p. 209, 1911).

3. Variscite from Utah.—In the same Proceedings (1912, p. 413) Mr. W. T. Schaller describes specimens of well-crystallized variscite from near Lucin in Utah. The mineral is found in a hard brecciated cherty or chalcedonic quartz-rock, which contains inclusions of nodules and streaks of limestone. It is a hydrous aluminium phosphate with traces of vanadium, chromium, and iron oxides, and it occurs in balls, nodules, and irregular masses in the chert. In colour the variscite ranges from a very pale green to a bright grass green. Gems are cut from it for pendants, brooches, pins, etc., but the stones are not adapted for rough wear.

4. Mining in South Australia.—A review of mining operations in South Australia during the half-year ended December 31, 1911, has been compiled by Mr. Lionel C. E. Gee, Chief Registrar of the Department of Mines. The mining operations, in order of importance, relate to copper, gold, salt, silver-lead, and other minerals, including phosphate, gypsum, pyrites, hæmatite, wolfram, and uranium-ore.

MISCELLANEOUS.

The Great Flood at Norwich.

Our readers will have learnt from the newspapers of the great calamity which has befallen the city of Norwich and large areas of Norfolk.

In November, 1878, disastrous floods occurred at Norwich after sixteen continuously rainy days, with some snow, when 4·50 inches of rain were recorded; and this was followed by an additional fall of 1·31 inches on November 15.

On August 26 and 27 of the present year the rainfall recorded at Norwich by Mr. A. W. Preston was as follows:—

	Inches.
August 26, 4 a.m. to 9 a.m.	1·03
,, ,, 9 a.m. to 6 p.m.	5·56
,, 26–7, 6 p.m. to 9 a.m.	·75
Total . .	7·34

Thus within one day there was a fall of more than $6\frac{1}{2}$ inches of rain, and in the course of twenty-nine hours no less than $7\frac{1}{3}$ inches. The weather has been described as a combination of a rain-storm and gale or blizzard, such as had never previously been recorded, and the consequent floods eventually surpassed all previous records. It was reckoned that the Parliamentary borough of Norwich, an area of 7,556 acres, received during about twenty hours more than five and a half million tons of water. The country around was being similarly deluged, and the results were that the low-lying portions of the city were soon flooded. By 3 o'clock on Tuesday afternoon (27th) the water had increased beyond the mark of the 1878 flood, and ultimately rose 16 ft. $6\frac{1}{2}$ in. above Ordnance Datum. The inundation of the streets arose at first, as is generally the case in times of excessive rain, by the choking of drains and gullies by rubbish and the pouring of water into cellars and basements of houses. Moreover, owing to the high wind, the rain was driven under tiles and slates, and few houses escaped some injury. The Wensum became a roaring torrent, but did not until August 27 overflow its banks in the city. The pressure of water in the sewers burst off the lids of the manholes, and fountains of water were thus liberated.

A considerable amount of earth was washed away from the Castle Mound; subsidences of ground took place here and there in the neighbourhood of Norwich; many roads have been reduced to a deplorable condition, and it was reported that more than eighty county bridges had been swept away or seriously damaged. The railways suffered by inundation, by the slipping of banks and embankments, and by the loosening of ballast, sleepers in places being washed away. The inundations extended in force from the city to Hellesdon, between the Dereham and Drayton roads, and elsewhere about Cringleford and Lakenham. Trowse Churchyard was flooded, likewise many kitchen gardens. Trees were blown down, and for a time the city was in darkness owing to the failure of the electric light during the evening of the 27th. The alluvial tracts bordering all the river valleys—Wensum, Yare, Tase, Waveney, etc.—were extensively flooded; and in West Norfolk considerable areas of marshland were inundated. The damage to farmers is most serious in the loss of live stock and ruin of crops. The waters began to abate on August 28, but it is yet early to estimate all the loss and damage which have been incurred.

For most of the above particulars we are indebted to the *Eastern Daily Press* for August 27–9.

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THE

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No. XI.—NOVEMBER, 1912.

ORIGINAL ARTICLES.

I.—NOTES ON BRITISH DINOSAURS.[1] PART V: *CRATEROSAURUS* (SEELEY).

By Dr. Baron FRANCIS NOPCSA.

IN the course of my researches among British Dinosaurs the kindness of Dr. J. E. Marr and Professor T. McKenny Hughes has enabled me to investigate closely the fragmentary bone which Professor Seeley described in 1874 under the new generic name of *Craterosaurus*.[2] Although the systematic position of the specimen had remained problematical from the day of its discovery, nevertheless the hope was entertained that in consequence of our present more ample knowledge of Dinosaurs and fossil reptiles in general, it might now be possible to determine the exact nature of this apparently most interesting fossil. The result was rather unexpected, for it became clear that what Seeley supposed to be the base of a cranium was nothing else than the neural arch of a dorsal vertebra showing the greatest resemblance to the corresponding element in *Stegosaurus*.

To prove the Stegosaurian affinities of *Craterosaurus* in a striking and convincing manner, two drawings of the fossil are given side by side in Fig. 1, together with corresponding figures of an American Stegosaurian vertebra in the British Museum (Natural History). As shown by the figure (Fig. 2) of the American *Stegosaurus*, Seeley's supposed occipital condyle is a process formed by the two fused post-zygapophyses (*pt.z.*), and the so-called base of the brain-cavity of *Craterosaurus* corresponds exactly with the spoon-like projection that is produced in Stegosaurs by the fusion of the two præ-zygapophyses.

In consequence of the concrescence of the right and left anterior and posterior zygapophyses, the cleft that is usually visible between the zygapophyses of Reptilian vertebræ, but is already very much obliterated in *Omosaurus Lennieri*,[3] is practically reduced to nothing in *Craterosaurus*, so that a curious kind of zygosphenal articulation is developed.

Besides the præ- and post-zygapophyses, one can also determine in *Craterosaurus* the position of the parapophysis, the diapophysis, a part of the neurapophysis, and even the position of the neural canal. The parapophysis (*pa.*) is formed in *Craterosaurus* as in *Stegosaurus* by a shallow well-marked depression, and represents the region which

[1] Part I, *Hypsilophodon*, GEOL. MAG., 1905; Part II, *Polacanthus*, loc. cit.; Part III, *Streptospondylus*, loc. cit.; Part IV, GEOL. MAG., 1911.

[2] H. G. Seeley, "On a Lacertilian Cranium from the Potton Sands": Quart. Journ. Geol. Soc., vol. xl, pp. 690–2, 1874.

[3] Nopcsa, "*Omosaurus Lennieri*": Bull. Soc. Géol. Normandie, tom. xxx, p. 11, anné 1910 (1911).

Seeley considered to be the surface of attachment for the alisphenoid. The fractured surface of the diapophysis (*d.*) is situated above and laterally of the parapophysis, where Seeley located the ex-occipital and the periotic; and the neural spine (*n.*) rose from the blunt, compressed, and broken ridge, which is well shown in Fig. 2 of Professor Seeley's drawings, though not specially mentioned.

All the bone of the vertebra of *Craterosaurus* situated below the zygapophyses corresponds to the column-shaped part of the Stegosaurian dorsal vertebræ between these and the neural canal. The more dense nature of the tissue at the bottom of this column-like part that was supposed by Seeley to indicate the vicinity of the pterygoid suture of the basisphenoidal hypapophysis, indicates according to our new interpretation the proximity of the neural canal, for in all Dinosaurs the walls of this canal are characterized by dense bony tissue.

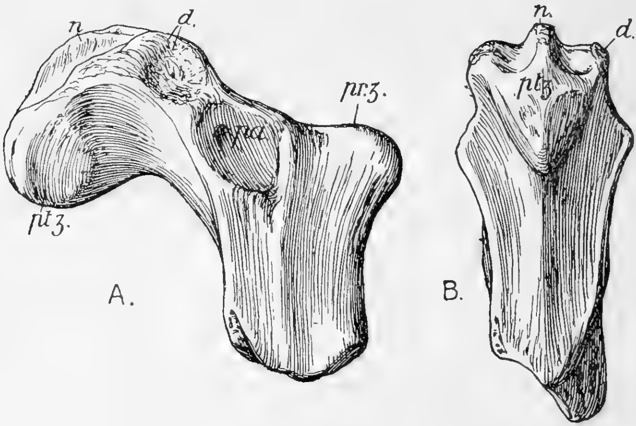


FIG. 1. *Craterosaurus pottonensis*, Seeley; part of neural arch in right side-view (A) and back view (B), one-half nat. size. Lower Greensand: Potton. [Type-specimen in Sedgwick Museum, Cambridge.] For lettering see Fig. 2.

A curious feature worthy of note is that in the middle of the column-like part, where most Stegosaurians show spongy bony matter, our fossil is perfectly hollow. Two irregular openings with fractured margins, the uneven surface of the hollow itself, and the much worn and rolled nature of the whole specimen suggest, however, that a great part of this cavity, if not the whole of it, may be due to post-mortem decomposition. In this case the influence of plant-roots, grass, moss, and water penetrating into small natural cavities of bones lying on the surface of the ground needs specially to be taken into account.

Having decided the anatomical character and general systematic position of the type-specimen of *Craterosaurus*, its generic position has to be considered. The unusually high position of the zygapophyses from the neural canal at once separates our fossil from

Scelidosaurus, from all well-known Acanthopholididæ (viz. *Polacanthus*, *Acanthopholis*, *Struthiosaurus*, and *Stegoceras*), from the Nodosauridæ (like *Ankylosaurus*),[1] and even from the Stegosaurid genus *Omosaurus*. Altogether *Craterosaurus* shows a striking resemblance to the genus *Stegosaurus*, and were it not for the fact that it seems hazardous to determine the exact position of so poor a "medal of creation", and that no Stegosaur has ever been found in so young a deposit as the Potton Sand, *Craterosaurus* might be considered as a synonym of

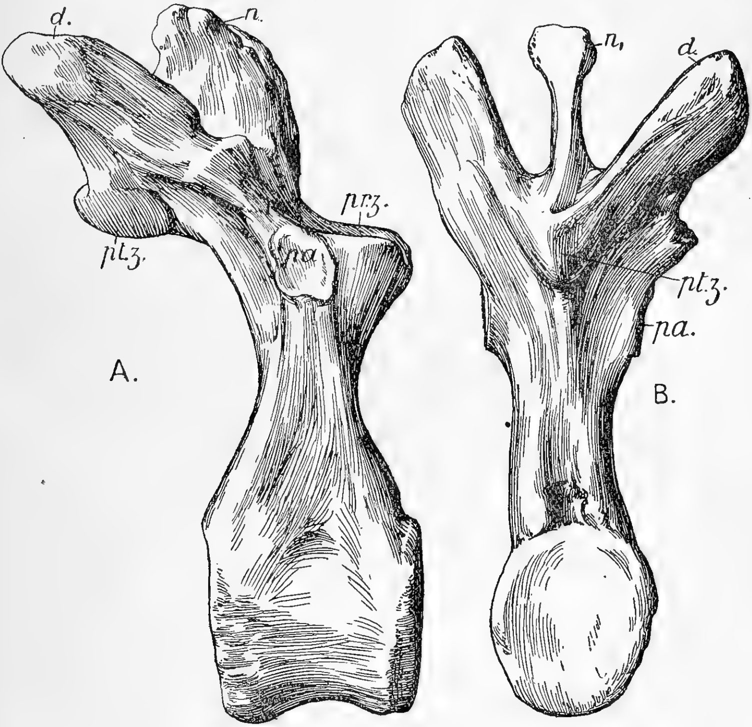


Fig. 2. *Stegosaurus* sp.; dorsal vertebra in right side-view (A) and back view (B), one-quarter nat. size. Upper Jurassic: Medicine Bend, Wyoming, U.S.A. [British Museum, No. R. 3216.] *d.* diapophysis; *n.* neural spine; *pa.* parapophysis; *pr.z.* præ-zygapophysis; *pt.z.* post-zygapophysis.

Stegosaurus; under the circumstances, however, it seems best to retain provisionally the name given by Seeley.

Great as Professor Seeley's error in the determination of *Craterosaurus* seems to be in the light of our present knowledge, it must be remembered that the fossil was described at a time when one knew

[1] The difference between the Acanthopholididæ and the Nodosauridæ (= Ankylosauridæ) is best seen in the structure of the cranium. Details will be published on some other occasion.

scarcely anything about extinct land reptiles. Nothing shows better how justified Seeley was in 1874 in considering the fragment of *Craterosaurus* to be part of a skull than the fact that since the original description, so far as I am aware, the cranial nature of *Craterosaurus* has never been questioned, at least in print. Had Seeley with the evidence then at his disposal originally described *Craterosaurus* as a neural arch of a dorsal vertebra, probably several of his learned colleagues would have supposed him to be mistaken. As a striking example of the great difficulties that the founders and pioneers of modern palæontology encountered in their early days, *Craterosaurus* thus possesses more than usual interest.

II.—The Uppermost Silurian and Old Red Sandstone of South Staffordshire.

By W. Wickham King, F.G.S., and W. J. Lewis, B.Sc.

(*Concluded from the October Number, p. 443.*)

2. *The Downton Castle or Yellow Sandstones* (see Figs. 2 and 3).—These occur at Lye and Turners Hill, but the best sections are at Saltwells. There the lowest beds are 10 feet of brown yellow and blue soft sandy mudstones (see Fig. 2, E^a), seen resting on the Ludlow Bone-bed, north of the Tram Bridge. Like the same zone at Ludlow, they are practically unfossiliferous.

To the north of this section there are some W.S.W. to E.N.E. faults that have let down some yellow Downton Sandstones which are studied best at "the (canal) Basin section" and Brewin's Tunnel.

The bottom of the Basin section is dolerite. Above it is this sequence:—

		ft.	in.
E^a	Greenish-yellow gritty hard sandstones: *Lingula Lewisii* (medium species), very abundant throughout	5	10
	Flaggy green sandstones	2	10
	Rubbly green and some yellow sandstones with many *L. Lewisii* (medium species)	4	9
	Yellow sandstone	1	6
	Rubbly light-green shales. *L. Lewisii* (smaller species) and fragments of fish scales	1	0
E^b	Very dark-green shale. *Platyschisma helicites*, *Modiolopsis complanata*, *L. minima* (rare), *L. Lewisii* (smaller species) very common	1	0
	Above the last there are 15 feet of yellow Downton sandstones with *Orbiculoidea rugata* and *L. minima*. On the south side of Brewins Tunnel the *Platyschisma* shale crops out immediately under the yellow sandstones which dip E.N.E. 31°.		
	Here the section continues thus:—		
E^c	One band of massive yellow sandstone with a fucoid bed at base. *L. minima* (common)	36	0
E^d	Fissile light-green shales 8 feet, passing into alternations of light-green shales, and rusty-red marly sandstones. *L. minima*	16	6
		69	5
	Add the lowest part of E^a at Tram Bridge	10	0
	Total of E exposed	79	5

The only Brachiopoda, we find, in E^a and E^b are *Lingulæ*. Mr. Lightbody at Ludlow "found *L. Lewisii* in the Upper Ludlow Series, but rarely; and near the top of that series abundance of another form, rather smaller, which he would be disposed to regard as *L. Lewisii* if that species had not been so rare in the Upper Ludlow".[1] A Eurypterid from E^b kindly examined by Dr. Bather is, he thinks, probably *Eurypterus pygmæus* (Salter).

At the basin section, Saltwells, E^a is crowded with *Lingulæ* as large as $\frac{8}{10}$ by $\frac{5}{10}$ of an inch, which are identical in form with *L. Lewisii*, but are much smaller than the *L. Lewisii* that occur in the Aymestry Limestone. They continue to the top of E^a.

In E^b a still smaller form of *L. Lewisii* is common, two of which measure $\frac{11}{20}$ by $\frac{8}{20}$ and $\frac{10}{20}$ by $\frac{7}{20}$. There are also *Lingulæ* which are rotund, for the two sides are not, as in *L. Lewisii* and *L. cornea*, fairly straight, but bulge out in a marked and distinctive manner. They are like those figured as *L. Symondsi* by Mr. Davidson in the *British Silurian Brachiopoda*, pl. iii, figs. 8, 9. *L. Symondsi*, so far as we are aware, has not, however, before been recorded at such a high horizon. Our specimens, out of E^b, gradually diminish in size and become elongated. The smallest and most elongated correspond with Mr. Davidson's dimensions and description of *L. minima*.

In South Staffordshire *Lingula Lewisii*, in its smaller forms, reaches E^b, which is a higher horizon than is recorded in the Ludlow district. Also *Orbiculoidea rugata*, which at Ludlow is rare in D^c, is found at Saltwells in E^c; and *R. nucula* and *O. elegantula* occur in D^c.

3. *Temeside or Eurypterus Shales* (see Fig. 4).—The magnificent section at Brewins Tunnel continues, at the same dip, uninterruptedly thus:—

		ft.	in.
F^a	Yellow-white quartzitic sandstone with black markings . . .	1	9
	Purple and green shales. *L. minima*, *L. cornea*, and Eurypteridæ	3	0
	Rusty-red marly sandstones. *L. cornea*	3	9
	Light green-yellow soft sandstones. *L. cornea* and *minima* .	10	3
	Rubbly green shales and marls with some micaceous purple shales. *L. cornea*, Eurypteridæ, *Cephalaspis Murchisoni*, *Onchus*, *L. minima*, etc.	5	0
F^b	Bone-bed limestone. *L. cornea* and many fragments of Eurypteridæ		4
	Green shales	3	5
F^c	Flaggy sandstones	2	0
	Red shale		6
F^d	Bone-bed limestone. *L. cornea* and many fragments of Eurypteridæ		4
F^e	Green shale		$4\frac{1}{2}$
	Calcareous yellow-green micaceous grit		$1\frac{1}{2}$
	Green shale	2	6
F^f	Calcareous yellow-green micaceous grit. *L. cornea*		2
		33	6

The two calcareous yellow-green grits are similar to the beds which occur in the vicinity of a bone-bed limestone where it passes either

[1] *The Silurian Brachiopoda*, pp. 35, 36.

horizontally or vertically into calcareous sandstone. They form two harder ribs in the midst of the softer material. The Temeside

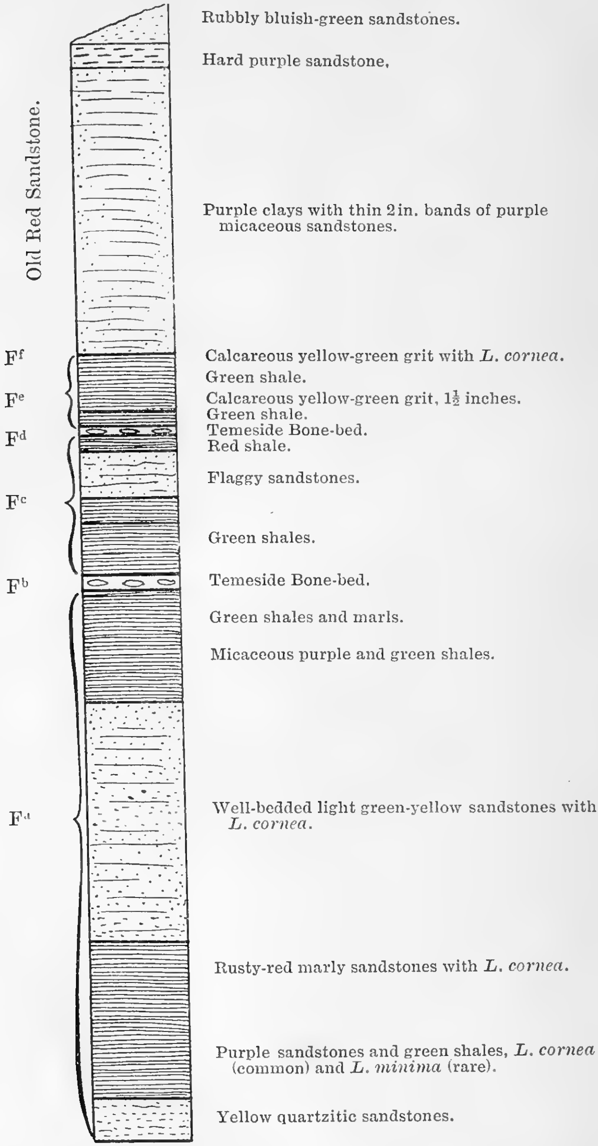


FIG. 4. Section at Brewin's Tunnel of Temeside Beds and some of the overlying strata. Scale 8 feet = 1 inch.

Bone-beds and shales occur along the west side of the reservoir, and here *L. minima* occurs abundantly within a few inches of F^b.

We divide E and F where *L. cornea* first occurs, though they might be regarded as one gradual transition from Silurian to Old Red Sandstone conditions.

Miss Elles and Miss Slater recorded two important palæontological changes in the uppermost Silurian of the Ludlow district, and we find the same at Saltwells.

At Saltwells the two great breaks are at the Ludlow Bone-bed and the Temeside Bone-beds. Below the former Brachiopoda abound, whilst above it they are rare, except *Lingulæ*. At and below the calcareous yellow-green grits and two Temeside Bone-bed limestones there is ample palæontological evidence; whilst above them the strata become thick purple or light-green or blue marls and highly micaceous purple and light-green sandstones, in which it is difficult to find fossils. We think we are justified, on these grounds, in regarding all the beds at Saltwells between F^f and the conglomerate at the base of the Coal-measures as being Old Red Sandstone.

4. *The Old Red Sandstone.*—The Brewins Tunnel section continues at the same dip and regular bedding as the Temeside Shales, thus:—

	ft.	in.
Purple marls with thin (2 in.) bands of micaceous purple sandstones	12	0
Hard purple sandstone	1	0
Rubbly bluish-green sandstone	3	0
Micaceous purple and bluish-green sandstone	4	0
Micaceous bluish-green fissile sandstone underlying a conglomerate at the base of the Coal-measures. We cannot find any recognizable fossils in these beds	2	0
	22	0

Underlying the Coal-measure conglomerate, dipping west, that crops out over 150 yards to the W.N.W. of the tunnel, there are purple and green marls and sandstones in which a few obscure fossils have been found by us. Mr. Lewis has located basaltic intrusions in these beds which pass up into the Coal-measure Series.

Some 25 yards east of Messrs. Doulton's engine-house is this upward sequence, dipping S.S.E. 33°–40°—

	ft.	in.
Yellowish-brown sandstones	3	0
Ochre and bluish-red marls or clunch with (fish ?) scales and *Onchus*	3	6
Red beds, with decomposed basalt, underlying Coal-measure yellow grits	4	0
	10	6

Mr. C. F. E. Griffiths kindly supplied to Mr. King details and a specimen of a pebble-bed, largely composed of angular pieces of rock similar to the above bluish-red marls, that was found 190 feet below the Thick Coal, three-quarters of a mile to the S.S E. at Saltwells Colliery No. 24, resting on 6 feet of binds.

The best sections of the Old Red Sandstones are in Black Brook, Saltwells Wood. Here the basal Coal-measure conglomerate can be seen resting directly on well-bedded purple, green, and brown micaceous sandstones interstratified in a thick mass of purple with some bands of light-blue marls. One band (south of the bridge) is a pebbly marl. Dr. A. Smith Woodward has kindly examined a few fossils found, and identifies a large specimen of *Onchus Murchisoni* (Agassiz) and fragments of various Ostracoderms. The dip is W.S.W. and west at angles varying from 50° to 16°, the steepest angles being on the western side of the strip. At the Leys Colliery, a quarter of a mile to the west, 261 feet below the Thick Coal, they pierced 25 ft. 8 in. of dark gritty rock and conglomerate, and then 3 feet of light-blue clunch and 60 feet of red clunch (marl).[1] The purple beds of Black Brook are nearly 200 feet thick. They clearly occupy a horizontal distance, at right angles to the strike, exceeding 300 feet; and then higher up the hill 400 feet to the east, at Lodge Farm, Downton Sandstones (E^c) with *Lingula minima* (common), *Modiolopsis complanata*, and *Beyrichia* sp. emerge also dipping west 35°. The brine bath well at Saltwells pierces the Old Red. The Saltwells Old Red compares favourably with this upwards sequence at Trimpley, near Kidderminster, 9 miles to the south-west, namely, (1) Temeside Bone-bed, 6 inches; (2) brown and yellow sandstones, 20 feet; (3) purple and green micaceous sandstones interstratified in a thick mass of purple marls.

Dr. W. Gibson, who has seen the Saltwells succession, points out that purple marls occur in the northern parts of the coal-field between the Millstone Grit and productive Coal-measures. He, however, agrees that it is improbable that the Black Brook purple beds are other than Old Red Sandstone, for they underlie a Coal-measure conglomerate which, according to our mapping, is the same as that at Brewin's Tunnel. Furthermore, within the coal-field the Carboniferous beds die out one after the other as they are followed southward, rendering it more likely that at Saltwells the Lower Carboniferous was removed by inter-Carboniferous denudation, as to which we give some facts below.

5. *The Base of the Carboniferous System.*—In the Saltwells Clay-pits the entire sequence from above the Thick Coal to the base of the Coal-measures is exposed. From the bottom of the Thick Coal to the base of the Coal-measures is 190 feet. The lowest of these rocks is a conglomerate 0 to 6 feet thick, passing upwards into yellow grits. The conglomerate varies in thickness, and in places dies out entirely. At Brewins Tunnel there are 28 feet of these grits and the conglomerate in the aggregate. The laminations are oblique. The largest pebble found at Saltwells is 14 by 10½ by 7 inches. At Saltwells these beds rest, in various sections, on different parts of the beds we include in the Old Red Sandstone, but in every section the dip agrees with the underlying rocks.

At the Hayes, Lye, one can see the conglomerate overstepping the

[1] *Silurian System*, 1839, p. 478. The lower part of the Carboniferous beds set out in this section crop out in Black Brook.

basset edges of, and then creeping up a small cliff composed of the Downton Sandstones. The strike of this little cliff is S.S.E. to N.N.W. A few yards away from the cliff the dip of the conglomerate and grits is 10° and of the underlying Downton Sandstones 30°. One immense pebble in the conglomerate is 36 by 18 by 18 inches. These observations confirm Mr. Jukes' views as to these deposits.[1] These basal rocks have been examined between the Lye on the south and Sedgley and Dudley on the north. The conglomerates are most persistent and coarsest to the south. The pebbles chiefly consist of quartzites, some of which are like the Cambrian quartzite that occurs in situ 5½ miles to the south-east of Lye at the Lickey. Pebbles of Llandovery Sandstone (*Pentamerus oblongus*), Silurian limestone, a clay ironstone nodule in which Dr. Arber has kindly identified *Neuropteris*, and pieces of coal also occur.

Comparison with the Ludlow District.

We wish to acknowledge the assistance that we have derived from Miss Elles' and Miss Slater's description of the uppermost Silurian of the Ludlow district, which is 28 miles W.S.W. of Saltwells.[2]

Their classifications, to a large extent, can be applied to South Staffordshire, but if one attempts, in the latter area, to adhere too closely to their palæontological zones, then difficulties arise, for certain fossils reach higher horizons in South Staffordshire than those recorded in Shropshire.

Mr. King examined the sections between Bow Bridge and the Mill Race, Downton, after we had nearly completed our work, and had previously examined the Whitcliff sections.

The Aymestry and Upper Ludlow groups are in the Ludlow district between 375 and 680 feet thick, whilst in South Staffordshire they are, say, 70 feet. The Upper Ludlow is 80 feet thick in the Tortworth district.[3] The flags and shales in B and C that are so thick at Ludlow are extremely thin in South Staffordshire, for A, B, and C form practically one band of limestone with only very thin partings.

Zone A of *Conchidium Knightii* can be determined. Above this zone our investigations, so far, only permit us to draw a line about 15–20 feet above the top of A, where we find the limestones are disappearing, and the bulk of the rock is calcareous sandstones in which *Chonetes minima* and *striatella* are very common. From this point to the Ludlow Bone-bed we treat as D. Between Zones A and D there is a zone where *Dayia navicula* is common, as at Ludlow. *Rhynchonella nucula* is, in the limestone bands, very abundant up to D^b, and is of no utility in South Staffordshire for determining a zone. D, though very much thinner than at Ludlow, does not differ to any very marked extent, except that we cannot fix by *Spirifera elevata* a zone D^b, that *R. nucula* and *O. elegantula* clearly ascend to D^c and perhaps still higher, and that *L. lata*, which at Ludlow occurs in B,

[1] *South Staffs Coalfields*, 2nd ed., p. 80.
[2] Q.J.G.S., vol. lxii, p. 195, 1896.
[3] Jukes-Browne's *Historical Geology*, 1st ed., p. 121.

ascends into D. *L. lata* at Saltwells is within 17 feet of D^c, and at Sedgley in the lower parts of D.

The Downton Castle Sandstones (E) at Forge Bridge, Downton, that are included in E^e, are thinly-bedded micaceous yellow sandstones. There are no such sandstones at Saltwells. Are they represented at Saltwells by the rusty-red marly sandstones at the top of E^d? At Saltwells E^d contains finer and more marly materials than E^d and E^e at Downton. Whilst *Platyschisma helicites* is very abundant at Downton Castle Bridge, we have to search carefully for a smaller species. *L. Lewisii*, which at Ludlow is rare in D^c, ascends abundantly in its smaller forms at Saltwells up to E^b. The Downton Sandstones at Saltwells are thicker, especially E^a and E^c. At both localities the massive yellow sandstones occur and have at their base the important *Platyschisma* shale.

The Saltwells Beds of Temeside age contain a quartzitic sandstone, and are more marly than those at Downton. Our Fig. 4 compares in thickness and zones very favourably with Miss Elles' and Miss Slater's figs. 6 and 7. But *L. minima*, rare at Ludlow in F^a, is common at Saltwells within a few inches of F^b. It is significant that the two bone-beds, F^b and F^d, and the two grit bands above are much more calcareous than any Mr. King could find in the Temeside Beds of the Downton district. Mr. Lewis finds that the composition of both F^b and ^{d} varies in the different samples of the same layer. Their average composition is approximately 36 per cent of sand and clay and 64 per cent of calcium carbonate.

The Igneous Rocks.

Mr. Lewis has examined the igneous rocks. They contain olivine (fresh), augite, often highly decomposed into chloritic products, felspar, intermediate between labradorite and andesine, and small quantities of magnetite. The felspar is centrally kaolinized, and the rock is traversed by calcite of secondary origin. The magnetite crystals show their crystal outline, and the felspars in rectangular sections are embedded in plates of augite. The rock is entirely free of glassy material, the residual magma having given rise to a second generation of felspars and augite. The rock is therefore an ophitic olivine dolerite.

In the field all the forms of basaltic jointing are shown, the most prominent being the spheroidal, with spheroids ranging up to a foot in diameter. The line of junction between the aqueous and the igneous rocks is distinctly marked. Fossils can be found at the junction, so contact metamorphism is very limited.

The dolerite is confined to the core of the anticline, and on both sides of the axis of the fold it tapers off in sills, some of which run into the Coal-measures. The dolerite appears as the crown of a laccolite sending out tongues into the sedimentary series.

There is an intimate relation between the faulting and the intrusions. At Brewins Tunnel the dolerite can be seen following the fault plane, and the microscope reveals incorporated fragments of sand grains which form part of the fault rock. The intrusion is therefore later than the formation of the W.S.W. to E.N.E. faults.

Movement along these fault planes may have taken place at widely different times, but we cannot find a section which would enable us to determine how far the basalt has partaken in the later movements.

Our investigations have resulted in these discoveries in South Staffordshire and North Worcestershire.

The Aymestry and Upper Ludlow groups are about 70 feet thick, as compared with 375 to 680 feet in the Ludlow district.

The following measures occur which have not hitherto been found at the surface:—

		Feet.
	Lower Old Red Sandstone, about	200
F.	Temeside Shales and Bone-beds	33
E.	Downton Castle or Yellow Sandstones with the *Platyschisma* shale	80
D^c.	The Ludlow Bone-bed. Not over	2
		315

Taken as a whole, without going into minute details, there are many similarities between the uppermost Silurian of Ludlow and South Staffordshire. In both areas the *Conchidium* limestone, *Chonetes* flags with the Ludlow Bone-bed, Downton Sandstone with its associated *Platyschisma* shale, and Temeside Shales and Bone-beds occur all in their regular order; and although some horizons do vary lithologically and palæontologically, yet these variations are such as might be accounted for on the assumption that in South Staffordshire and North Worcestershire the waters were throughout the period deeper and clearer, resulting in thinner, finer, and more marly and calcareous sediments being deposited, and in certain fossils, especially the different species of *Lingulæ*, surviving to higher horizons.

We heartily thank Mr. Willetts and other officers of the Birmingham Canal and Messrs. Doulton & Co. for the facilities they have granted to us in connexion with our investigations, and also Mr. Coulson, Principal of the Dudley Technical School, for the use of the chemical laboratory.

III.—The supposed Cretaceo-Tertiary Succession of New Zealand.

By Professor James Park, F.G.S.

THE theory of a Cretaceo-Tertiary succession in New Zealand was first formulated by Captain Hutton in the early seventies mainly on the evidence of the Waipara sections in North Canterbury, where there appeared to be an unbroken succession from the Cretaceous into the Lower Tertiary. He correlated the Weka Pass Stone with the Ototara Stone, and in the main his views were adopted by Sir James Hector and the Geological Survey.

Further investigation showed that the Ototara Stone in its typical localities in North Otago and South Canterbury was conformably underlain by a great succession of marine and terrestrial Lower Tertiary strata, while in North Canterbury the Weka Pass Stone was underlain by a great succession of Cretaceous strata. Obviously the Cretaceous strata could not be the time equivalent of the Tertiary strata. Captain Hutton, who still correlated the Weka Pass Stone with the Ototara Stone, soon abandoned the Cretaceo-Tertiary succession and introduced an unconformity between the Weka Pass Stone and the underlying Amuri Limestone, the hiatus representing as he believed the series of Tertiary strata which underlies the Ototara Stone in South Canterbury and North Otago.

If the Weka Pass Stone is the horizontal equivalent of the Ototara Stone, it is obvious that Captain Hutton's contention was unassailable. The position will be easily understood by a reference to Fig. 1.

The Tertiary beds *b*, *c*, *d*, varying from 400 to 1,000 feet thick, are absent in the North Canterbury sections.

After my first examination of the Waipara sections in the eighties I became an ardent supporter of the Cretaceo-Tertiary succession; but a wider knowledge of our younger rocks gained in later years convinced me that the position was untenable, and like Captain Hutton, its originator, I was reluctantly compelled to abandon it.

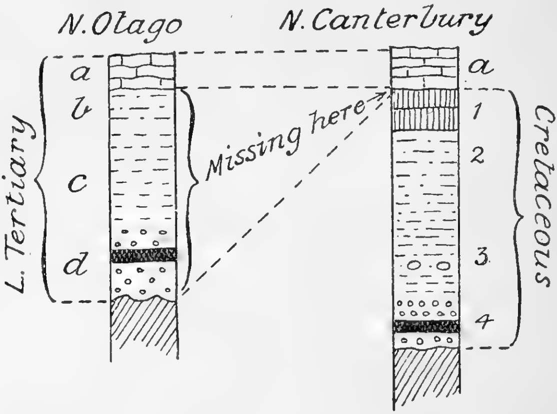


FIG. 1. *Tertiary:* (*a*) Ototara Stone; (*b*) glauconitic sands; (*c*) marly clays and sands; (*d*) quartzose sands with fireclays and brown coal.
Cretaceous: (1) Amuri Limestone; (2) glauconitic sands; (3) shaly clays with septarian concretions containing Saurian remains; (4) quartzose sands with shales and brown coal.

After a lapse of nearly a quarter of a century Dr. Marshall and his colleagues view the Waipara sections, and, influenced by the apparent conformity of the Tertiary and Cretaceous strata, become enthusiastic advocates of the Cretaceo-Tertiary succession. The contentions I used in favour of the succession are now quoted against me. Of this I do not complain. I did the same with Captain Hutton. To the young geologist there is always something attractive and alluring about a Cretaceo-Eocene succession, and I have no doubt that its recrudescence will be periodic with every new generation of geologists.

Dr. Marshall recognizes that the Ototara Stone is conformably underlain by a great succession of marine beds containing a Tertiary fauna, and the Weka Pass Stone by a Cretaceous fauna. This leads him to revive the theory of overlap, which was frequently discussed in the old Geological Survey days, but found to be untenable, since at places as distant as North Auckland and as far south as South Otago both the Lower Tertiary and Cretaceous faunas are found in juxtaposition.

At Wade, north of Auckland, the Waitemata Beds rest highly unconformably on the Cretaceous strata. Dr. Marshall is in error in saying that this section was not described when first discovered.[1] The actual junction of the Tertiary Waitemata and the Cretaceous beds is beautifully exposed in a vertical sea-cliff, and the figure which accompanied my report is reproduced below.

The septarian beds everywhere in the North Auckland district underlie the hydraulic (Amuri) limestone, notably at Wade, Mahurangi, Hikurangi, Kawa-Kawa, and Batley, opposite Komiti Point. Moreover, as reported at the time, I discovered blocks of hydraulic limestone in the Lower Waitematas near Howick and Onehunga.

No geologist has ever doubted the Oamaruian age of the Waitematas; and the hydraulic limestone is a member of the Cretaceous coal formation, as proved by boreholes at Kawa-Kawa.[2]

At Shag Point in Otago, as described by me in the December, 1911, issue of the GEOLOGICAL MAGAZINE,[3] the Cretaceous strata

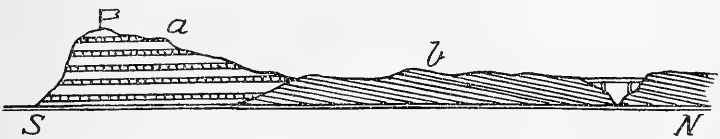


FIG. 2. Section Orewa Bridge to South Head. (*a*) Thin-bedded Tertiary sandstones and clays; (*b*) sandy clays with septaria.

form the north wall of the Shag Valley. They are sharply tilted and folded, and rest on the Palæozoic mica-schists. The floor of the valley is occupied by horizontal or gently dipping Lower Tertiary strata, typically Oamaruian, which, as so clearly brought out by Mr. A. Gordon Macdonald in his carefully contoured geological maps of this area, abut against the Cretaceous Series from the head of the valley to the sea, and going southward rest on the mica-schists.

Professor Cox and Mr. A. McKay believed that a fault existed along the north side of the Shag Valley, and this view fitted in quite consistently with the old view of the Geological Survey that the Tertiary beds in the floor of the valley were the horizontal equivalents of the Cretaceous Shag Point Beds. But Dr. Marshall rightly enough recognizes that the Tertiary beds cannot be the time equivalents of the Cretaceous Shag Point Beds, and contends that the Tertiary beds follow the Shag Point Beds conformably, but have been faulted down to the floor of the valley. The supposed fault was the natural

[1] Geol. Reports and Explorations, 1886–7, p. 226.

[2] A. McKay, Geol. Reports and Explorations, 1883, p. 133.

[3] J. Park, "The Unconformable Relationship of the Lower Tertiaries and Upper Cretaceous of New Zealand": GEOL. MAG., Dec. V, Vol. VIII, No. 570, pp. 539–49.

corollary of the view of the old Survey, but is entirely opposed to that of Dr. Marshall, for obviously if the Tertiary beds follow the Cretaceous conformably they should rest, not on the basement mica-schists, but on that portion of the Cretaceous from which they are supposed to have been dissevered.

Dr. Marshall,[1] when discussing the Shag Point section, lays much stress on the circumstance that the actual contact of the horizontal Tertiaries and uptilted Cretaceous is obscured by recent detritus. He infers all kinds of geological possibilities between the junction, but

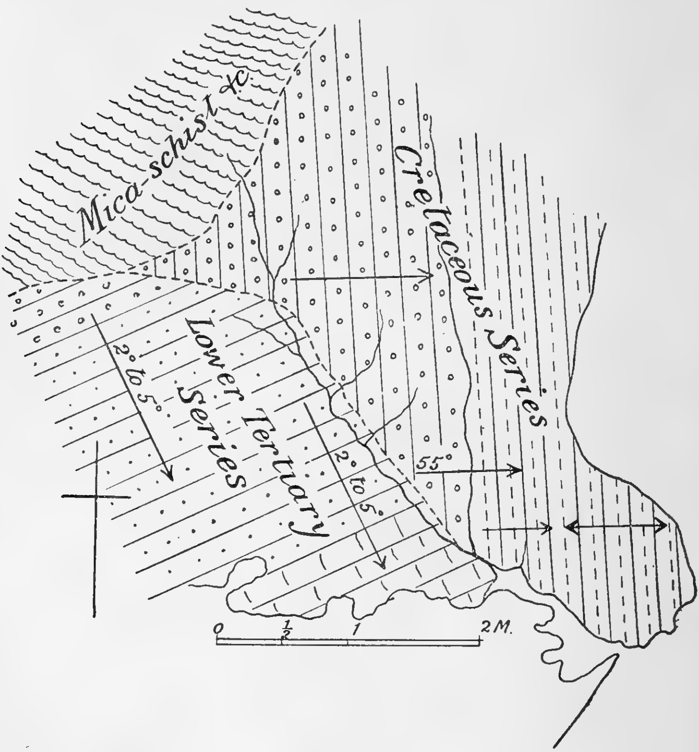


FIG. 3. *Tertiary Series:* (*a*) Calcareous sandstone; (*b*) glauconitic sandstone; (*c*) blue clays and soft sandstones; (*d*) quartzose conglomerate with brown coal; (*e*) mica-schist.

Cretaceous Series: (1) Greensands and shaly clays with septarian concretions; (2) gritty sandstones; (3) quartz sands and conglomerates with brown coal; (4) quartzose conglomerates passing into quartzose and mica-schist breccia.

nevertheless invokes the aid of a fault running along the junction, seemingly failing to recognize that the effect of the fault would be to make the two formations abut against one another. Such veteran

[1] GEOL. MAG., July, 1912, p. 318.

geologists as Sir James Hector, Mr. Alexander McKay, Sir Julius von Haast, and Professor Cox had no misgivings on this point when mapping the Shag Point district.

In his reference to the Kaitangata district in South Otago Dr. Marshall[1] says that since no actual contact of the Lower Tertiary and Cretaceous formations are seen, "obviously this unconformity is a matter of inference." But the unconformity cannot be so lightly disposed of as this. When dealing with the Shag Point section he has also, as we have seen, laid great stress on this contention that there is no visible contact. He fails to realize (*a*) that visible contacts between different formations are not the rule, but the exception; and (*b*) that a field-geologist has no difficulty in delineating the distribution of two formations that are petrographically and palæontologically different, more especially when the general arrangement of the strata comprising the formations lends its powerful assistance. The Kaitangata and Tertiary coal-bearing formations differ as widely as the proverbial chalk and cheese, as may be seen by a perusal of the following tabulated statement:—

Tertiary Formation.	Kaitangata (Cretaceous) Series.
(*a*) Limestone (glauconitic).	(*a*) Compact sandstones and shales.
(*b*) Hard limestone.	(*b*) Hard greywacke conglomerates with numerous seams of superior bright-brown coal.
(*c*) Glauconitic sands.	(*c*) Brown sandstones with calcareous horizon containing marine shells.
(*d*) Quartzose sands and conglomerate with lignite seam.	(*d*) Thick bands of quartzose conglomerate and quartzose sands with seam of lignite.

The Kaitangata Series, which is bent into folds, rests directly on a highly eroded surface of the altered greywacke and slaty shales of the Kakanuian (Older Palæozoic) and mica-schists of the Maniototian; while the Tertiary Series, which is horizontal, lies in some places on the Kakanuian, in others wraps round the boundaries of the Kaitangata Beds in a way that clearly indicates unconformity, notwithstanding that the actual junction is obscured by glacial drifts and clays.

The Cretaceous Series contains two coal horizons, namely, a lower consisting of quartzose conglomerates and sands with one seam of lignite, and an upper consisting of massive bands of greywacke conglomerate containing many seams of hard bright coal.

The Tertiary beds contain a rich fauna that is distinctively Oamaruian. The Kaitangata marine horizon, which lies between the two terrestrial stages, contains *Conchothyra parasitica*, a peculiarly distinctive Cretaceous form, a new *Turritella* (*T. semiconcava*), *Belemnites lindsayi*, and a rich assemblage of undescribed mollusca that possess a facies resembling the fauna underlying the hydraulic (Amuri) limestone and overlying the coal at Kawa-Kawa in North Auckland. The point at issue is not so much one of conformity or unconformity as the more immediate one that if the overlap hypothesis be true the Cretaceous fauna ought not to exist in Otago.

[1] Geol. Mag., July, 1912, p. 318.

At New Brighton, near Dunedin, there is a remnant of the Cretaceous Series consisting of an impure rubbly sandy limestone underlain by loose quartzose sands and interbedded with fireclays and a seam of lignite. The marine bed contains many broken unrecognizable shells and a true Belemnite (*B. lindsayi*). The Cretaceous beds rest directly on the mica-schist, and are overlain by the dirty greenish-coloured soft micaceous sandstones of the neighbouring Tertiary coal series of Saddle Hill and Green Island, the complete succession of which is as follows, reading downwards :—

(*a*) Caversham sandstone (Ototara Stone).
(*b*) Glauconitic sands.
(*c*) Blue marine clays.
(*d*) Dirty green micaceous sandstones.
(*e*) Quartzose sands with a seam of lignite near the base.

In an interesting paper on the geology of the Lower Waipara Gorge[1] Mr. R Speight, one of Dr. Marshall's colleagues, describes the occurrence of a Tertiary fauna in the beds overlying the grey marls containing more than 30 per cent of living species. According to recognized standards the age of these beds should be, as he says, an Upper Miocene or Lower Pliocene. The grey marls consist of a horizon of sandy clays lying between the Weka Pass Stone and the Mount Donald Beds. Below the Weka Pass Stone we have only a Cretaceous fauna. Does not this biological discordance suggest a marked palæontological unconformity ? The stratigraphical conformity is only apparent ; the palæontological break is pronounced. Mr. Speight, while still adhering to the stratigraphical conformity of the Tertiary and Cretaceous Series, concludes with the significant remark : "This statement [*in re* conformity] does not, however, negative the existence of a palæontological break."

The calcareous beds which form the higher members of the Oamaru system are dominated by Brachiopods, Pectens, Echinoderms, Corals, and Foraminifera, only a few of which are represented by living species, while the underlying marine clays and sandy beds contain a rich fauna of Lamellibranchs and Gasteropods, of which, as found at Hampden, Ngapara, Black Point, Wharekuri, Waihao, Waipara, and Weka Pass, from 25 to 30 per cent are living species. Of the few species which range throughout the whole of the marine stages of the Oamaruian are *Pseudamusium huttoni* (Park) and *Cirsotrema browni* (Zittel). These two beautiful species are scarce in the blue sandy beds in which they first make their appearance, attain their maximum development in the glauconitic sands, and make their last appearance in the Ototara Stone, in which they are nowhere abundant. Their discovery in the Weka Pass Stone in the Waipara district as reported by Dr. Thomson and Mr. Cotton cannot be regarded as proving that the Weka Pass Stone is the time equivalent of the Ototara Stone. What it does prove is that Captain Hutton was right in placing the unconformity between the Oamaru and Waipara systems at the close of the Amuri Limestone. Moreover, the shattered and undulating

[1] R. Speight, "A Preliminary Account of the Lower Waipara Gorge": Trans. N.Z. Inst., vol. xliv, pp. 221–33, 1911.

surface of the Amuri Limestone which I critically examined last March for the first time seems to be corroborative of Hutton's view. The discordance is as well marked as that between the Cretaceous and Eocene of South England.

Dr. Marshall, by insisting that the absence of a marked physical break at Waipara between the Tertiary and Cretaceous strata is an evidence of a Cretaceo-Tertiary succession, seems to have overlooked the fact that the physical unconformity between the Cretaceous and Eocene in England is so slight that it is not visible in single sections, and is only capable of proof on palæontological grounds. Furthermore, in England the Eocene nowhere extends beyond the Chalk outcrop, thereby showing a closer physical relationship between these formations than exists in New Zealand, where the Lower Tertiary strata rest in most places on formations older than the Cretaceous.

It is worthy of note that the places where the Lower Tertiary system of New Zealand rests on the Cretaceous are few and widely separated. In most places the Tertiaries rest on older rocks. This widespread overlap beyond the Cretaceous outcrop is in itself significant. It is obvious that when the subsidence which ushered in the Tertiary took place, the first areas to be invaded by the Eocene seas would be the Cretaceous basins. The remarkable overlap beyond the Cretaceous outcrop seen throughout New Zealand may be therefore taken as an evidence of widespread and prolonged, if not rapid, subsidence at the close of the Cretaceous; while the large proportion of living species in the lowest marine beds of the Tertiary system may not unreasonably be held to mark a wider gap than that between the Cretaceous and Lower Tertiary of England.

Dr. Marshall's correlation of the Hutchinson Quarry Beds with the Weka Pass Stone is entirely at variance with the palæontological evidence. The Hutchinson Quarry Beds are intimately related to the Oamaru Stone, and contain a rich and distinctive fauna of Brachiopods, Pectens, Corals, and Bryozoans, that led Sir James Hector, Sir Julius von Haast, Captain Hutton, Professor Cox, and Mr. Alexander McKay without hesitation to correlate them with the Mount Brown or Mount Donald Beds, which lie 300 or 400 feet above the Weka Pass Stone in the typical sections in North Canterbury. All the palæontological evidence that has accumulated during the past twenty-five years has merely served to confirm the soundness of their correlation.

The Hutchinson Quarry Beds, consisting of glauconitic sands, tuffs, and limestones, together with the closely associated Oamaru Stone, are in my opinion the equivalents of the Kakanui Limestones = Ototara Stone = Waitaki Stone = Waikao Stone = Mount Somers Stone = Mount Brown and Mount Donald Stones in North Canterbury.

A critical review of the evidence seems to establish the view that we have two coal-bearing formations in New Zealand, as so long maintained by Captain Hutton, namely, the Waipara System, of Cretaceous age, and the Oamaru System, of Lower Tertiary age. Each formation begins with terrestrial beds containing seams of coal and closes with a calcareous marine horizon. The Cretaceous System rests on older Secondary and Palæozoic rocks, the Oamaruian on the

Cretaceous and older formations. In the Waipara district, where the terrestrial beds of the Oamaruian are absent, the physical break between the Cretaceous and Tertiary is not well marked, but the palæontological break is complete. In all other parts of New Zealand wherever the terrestrial beds of the Oamaruian are present, the stratigraphical break between the Cretaceous and Tertiary is as conspicuous as the palæontological.

IV.—The Chemical Examination of the Carboniferous Limestones of the Avon Gorge.

By Mildred B. Chapman, B.Sc., D.I.C.

In view of the attention which has been drawn of recent years to the mode of origin of the purer limestones, I have been led to prosecute some inquiries under this head on the Carboniferous Limestones of the Avon Gorge, near Bristol. I have paid greatest attention to the chemical composition of the rocks, particularly the proportion of insoluble residue remaining after treatment with hydrochloric acid; at the same time I have not wholly neglected the fossil contents, although for information on this point I have mainly relied on other observers.

The method of analysis which I adopted was similar to that used by Professor Skeats in his investigations on the Dolomites of the Tyrol, so that the results can easily be compared. Briefly it was as follows:—

The finely powdered limestone, after solution in strong hydrochloric acid and evaporation to dryness, was again moistened with the acid and evaporated. The mass was lixiviated with water containing a few drops of hydrochloric acid and the weight of residue determined. This residue was examined under the microscope, but I have not attempted to give a detailed description, as this has already been done by Mr. E. Wethered (Q.J.G.S., 1888). Iron and aluminium hydroxides were precipitated from the solution by means of ammonia, and the content of iron oxide and alumina determined as a whole.

The percentage of lime was ascertained by titration with potassium permanganate after precipitation by means of ammonium oxalate. Magnesia was weighed as magnesium pyrophosphate, obtained by precipitation with sodium phosphate and ammonia.

A separate estimation was made of the carbon dioxide in the usual manner, using soda lime for absorption.

Each specimen was also carefully tested for the presence of phosphoric acid.

Except when otherwise stated the figures given are the average of several analyses.

Sections of the same specimens of the rocks were examined microscopically and were treated with Lemberg's solution to distinguish the dolomite if present.

Specimens were collected throughout the Avon Gorge section except from the shale and argillaceous bands, which were neglected, as they do not come within the scope of this paper. Special care was taken to obtain samples from all marked coral bands.

The classification of the beds is that laid down by Dr. Vaughan (Q.J.G.S., 1905).

Tournaisian.

a. Modiola Phase.—The passage beds between the Old Red Sandstone and Carboniferous Limestone.

Ca O	44·34
Mg O	5·23
C O_2	43·51
$Fe_2O_3 + Al_2O_3$	1·98
Insoluble residue	5·22
Total	100·28

The insoluble residue in various specimens of this zone varies between 3·24 per cent and 11·18 per cent, and consists chiefly of quartz flakes and rounded detrital quartz, felspar (much weathered), and carbonaceous material, mainly bitumen. A few microscopic crystals of zircon, some sponge spicules, and casts of crinoid ossicles preserved in chalcedony are also present. The proportion of insoluble residue is unusually large, as is to be expected in view of the probable proximity of slowly sinking Old Red Sandstone land areas.

No corals have yet been recorded from these beds, and it thus appears that they do not represent coral reefs.

K. Cleistopora Zone.

K_1. *Productus bassus* subzone.

	A.	B.
Ca O	45·83	48·21
Mg O	6·53	2·16
C O_2	43·26	44·72
$Fe_2O_3 + Al_2O_3$	·94	·43
Insoluble residue	3·71	4·53
Total	100·27	100·05

The insoluble residue content varied from 2·41 to 4·53 per cent. Analysis A shows the average composition and B that of the specimen having the greatest proportion of insoluble residue.

The residue consists of well-rounded detrital quartz, chalcedonic silica, small zircons, much kaolinized felspar, and some tourmaline.

K_2. *Spiriferina octoplicata* subzone.

	A.	B.	C.
Ca O	50·93	49·44	51·04
Mg O	6·07	7·42	6·28
C O_2	42·70	43·54	42·42
$Fe_2O_3 + Al_2O_3$	·42	·38	·45
Insoluble residue	·21	·19	·07
Total	100·33	100·97	100·26

A, B, and C give the analyses of the lower, middle, and upper portions of this subzone respectively.

The percentage of insoluble residue varies between ·07 and ·21, and is therefore very low.

Corals are rare throughout the subzone, occurring most abundantly at the top. Brachiopods are plentiful, especially *Spiriferina octoplicata.* This cannot be a coral reef from which the coral structure has since disappeared, as the Brachiopods and some Corals still remain without the loss of their structure.

It is therefore a chemically pure limestone which nowhere exhibits the structure of a coral reef.

β. Passage beds between K and Z zones.

CaO	41·99
MgO	9·99
CO_2	42·53
$Fe_2O_3 + Al_2O_3$	·63
Insoluble residue	4·95
Total	100·09

The insoluble residue consists chiefly of detrital quartz and black carbonaceous material. Analyses of different parts of these beds gave very constant results, the amount of insoluble residue only varying between 4·78 per cent and 4·96 per cent.

Z. ZAPHRENTIS ZONE.

Z_1. *Spirifer clathrata* subzone.

	A.	B.
CaO	46·34	32·95
MgO	2·17	16·76
CO_2	36·30	39·74
$Fe_2O_3 + Al_2O_3$	·61	·29
Insoluble residue	14·51	10·34
Total	99·93	100·08

A and B are analyses of those specimens which have the greatest and least amount of insoluble residue. This residue consists of detrital quartz, quartz with secondary deposition of silica, small zircons, and some pyrites; most of the material was much rounded, as if by current action or under littoral conditions.

Z_2. *Zaphrentis konincki* subzone.

CaO	55·63
MgO	1·73
CO_2	42·22
$Fe_2O_3 + Al_2O_3$	·29
Insoluble residue	·43
Total	100·30

The percentage of insoluble residue varies from ·37 to ·46—most of this is silica; secondary deposition has often formed perfect doubly terminated crystals. Minute zircons, fragments of tourmaline, some carbonaceous material, and small quartz flakes also occur.

Marked coral bands occur throughout this subzone.

γ. Passage beds between zones Z and C.

CaO	41·99
MgO	10·68
CO_2	41·43
$Fe_2O_3 + Al_2O_3$	·93
Insoluble residue	4·95
Total	99·98

The insoluble residue resembles that of the Z_2 subzone.

These beds are approximately contemporaneous with the igneous rocks of the Weston-super-Mare district, and the proximity of this area, combined with current action, may account for the great variation in the amount of insoluble residue between the base of the Z and the beginning of the C zone.

C. Caninia Zone.

C_1. (1) *Laminosa* Dolomite; (2) *Caninia* Oolite.

C_2. (3) *Caninia* Dolomite.

	(1)	(2)	(3)
CaO	45·19	55·58	42·98
MgO	10·32	—	10·94
CO_2	43·62	44·22	42·04
$Fe_2O_3 + Al_2O_3$	·38	·15	·49
Insoluble residue	·75	·05	3·48
P_2O_5	trace	·14	·12
Total	100·26	100·14	100·05

The percentage of insoluble residue is low, being never greater than 3·48 per cent and usually below 1 per cent. In view of the proximity of igneous action the low percentage of insoluble residue is remarkable.

The residue consists of black carbonaceous material with some bitumen, greyish devitrified glass, brown-stained quartz grains, some minute flakes of quartz, and chalcedonic silica. These beds contain an appreciable amount of phosphate, probably calcium phosphate.

Viséan.

S. Seminula Zone.

S_1. *Productus* aff. *semireticulatus* subzone.

	A.	B.
CaO	46·34	48·21
MgO	2·07	·84
CO_2	36·39	37·93
$Fe_2O_3 + Al_2O_3$	·58	5·87
Insoluble residue	14·50	7·41
Total	99·88	100·26

Analyses A and B correspond to the specimens having the greatest and least percentage of insoluble residue. The high percentage may be due to igneous activity in the adjacent district of North Somerset, but the direction of the prevailing currents would have to be materially different from that of the period during which the immediately preceding rocks were deposited, as they contain a very small amount of insoluble residue. No diminution in the percentage of insoluble residue was detected in the marked coral bands.

The residue consists of well-rounded detrital quartz, often brown-stained, bitumen, other fine carbonaceous material, and siliceous sponge spicules. Quartz flakes occur in the upper part.

S_2. *Productus cora*, mut. S_2 subzone.
Seminula Oolite.

CaO	54·82
MgO	·68
CO_2	44·16
$Fe_2O_3 + Al_2O_3$	·12
P_2O_5	·12
Insoluble residue	·26
Total	100·16

As is usual in the Oolitic limestones there is very little impurity. The MgO cannot be seen as dolomite rhombs in thin sections of the rock even when treated with Lemberg's solution, and can only be detected on analysis.

The insoluble residue consists of fine argillaceous material, quartz with secondary growth, zircons, pyrites, and well-developed siliceous sponge spicules. No carbonaceous material is present.

No coral bands occur, so the small amount of insoluble residue cannot be due to the formation of these beds under coral-reef conditions.

D. Dibunophyllum Zone.

D_1. *Dibunophyllum* θ subzone.

	Base.	Middle.	Top.
CaO	49·50	55·60	29·38
MgO	5·92	—	·82
CO_2	41·96	44·05	24·62
$Fe_2O_3 + Al_2O_3$	·21	·08	2·15
Insoluble residue	2·51	·45	43·29
Total	100·10	100·18	100·26

The insoluble residue is mainly rounded detrital silica and quartz flakes. Much carbonaceous material occurs at the top, bitumen in one case constituting 4·16 per cent of the entire rock.

D_2. *Lonsdalia floriformis* subzone.

CaO	54·96
MgO	—
CO_2	43·41
$Fe_2O_3 + Al_2O_3$	·66
Insoluble residue	1·84
Total	100·87

The content of insoluble material varies between ·02 and 2·41 per cent—it is chiefly quartz and fine argillaceous material. The *Dibunophyllum* zone contains many marked coral bands, and was probably deposited under "coral-reef conditions". It contains a very variable amount of insoluble residue up to as much as 43·29 per cent.

On examining the foregoing results it will be seen that the beds which have been formed under coral-reef conditions have a very variable amount of insoluble residue.

In the rocks analysed it varies between ·43 in Z_2 and 43·29 in D_1. On the other hand, rocks which do not appear to have been formed under coral-reef conditions, e.g. K_2, are remarkably pure. On the whole the lowest proportion of insoluble residue was obtained from the Brachiopod limestones and the Oolitic bands.

My examination therefore confirms the view expressed by Professor Skeats ("Dolomites of the Southern Tyrol," Q.J.G.S., 1905), viz., that chemically pure limestones are formed by rapid deposition near a coastline which is usually composed of calcareous rocks, from the waste of which the material is obtained.

On the other hand, I have obtained no evidence that such limestones are formed necessarily under coral-reef conditions, but rather that such conditions are by no means essential, and that the amount of insoluble residue depends on the action of the currents.

The analyses in this paper were carried out in the Geological Laboratories of the Imperial College of Science and Technology, and I wish to express my gratitude for much kind advice and assistance to Professor W. W. Watts and other members of the staff of the College.

V.—Cambrian Geography.

By A. J. Jukes-Browne, F.R.S., F.G.S.

PROFESSOR PEACH'S address, as President of Section C at the recent meeting of the British Association, concludes with some interesting remarks on the geographical conditions of Cambrian time, and these may be regarded as an amplification of the views which he had previously expressed to the Royal Society of Edinburgh (1886) and in the Geological Survey memoir on the *Structure of the N.W. Highlands of Scotland* (1907).

I had occasion to comment on these views in the recent edition of my *Building of the British Isles* (1911), and am glad to find I correctly interpreted his original suggestion as meaning that a sea with continuous shore-lines stretched across the Atlantic region from Canada to Ireland, and that this sea separated two different zoological provinces of littoral Invertebrata.

In this general statement there is now a complete agreement between us, because, as he says, it seems a reasonable inference from the palæontological evidence, but it is not so easy to follow the arguments by which he endeavours to support the more detailed exposition of his hypothesis.

He begins by assuming that the materials of the Torridon Sandstone and of the newer Algonkian rocks of Canada were derived from a land which formed a continuous belt from Scandinavia to North America. He continues: "During the period which elapsed between the deposition of the Torridon Sandstone and the basement members of the Cambrian system a geosyncline was established which gave rise to a submarine trough, trending in an E.N.E. and W.S.W. direction both in the British and North American areas. In the latter region it extends from Newfoundland to Alabama, its south-eastern limit being defined by the old land surface of Appalachia. The extension of this Appalachian land area in a north-east direction, beyond the limits of Nova Scotia and Newfoundland, was postulated by Dana and other American writers."

It will be seen that the statements in this passage are not consistent with one another. A trough which passed across the Atlantic from Scotland to Newfoundland would, if prolonged, extend to Iowa and not in the direction of Alabama. The line from Alabama to Newfoundland is very nearly south-west to north-east, and if prolonged would pass through Iceland, but would not touch Scotland nor even the extreme north of Norway.

The Appalachian ranges and the Caledonian flexures are parallel to one another, not parts of a continuous ge-anticline. Moreover, they were formed at a much later date in the world's history, and there is no reason for supposing that they were in any sense initiated in Cambrian time, or that there was a corresponding geosyncline "which remained a line of weakness throughout Palæozoic time". I need hardly point out that parallel ge-anticlines, one in Europe and one in North America, would not form a connecting shore-line between the two regions.

The fact is that Professor Peach is only correct so far as the W.S.W. line from Scotland to Newfoundland is concerned, and there is no need for the introduction of a geosyncline of any kind. All that the facts warrant is the inference that there was a continuous coastline from Norway to Canada with open sea to the south of it. This coastline would have a general trend from E.N.E. to W.S.W., but may in many places have run nearly due east and west.

If this is granted the rest of Professor Peach's restoration becomes comprehensible and probable. Instead of the Cambrian rocks of the North-West Highlands being "laid down along the N.W. side" of a trough or geosyncline, they were really formed along the northern border of a North Atlantic sea, that is, on the southern side of an east and west tract of land extending from Norway to Greenland and Labrador.

Further, he now agrees with me that the Cambrian strata of Wales were deposited along the southern side of this sea, and he thinks that "this southern land area in Western Europe was continuous across the Atlantic with Appalachia". Presumably the northern shore of this land ran from Cornwall to Nova Scotia, crossing the Atlantic in a general east to west direction, more or less parallel to that of the northern land. It is of course a big assumption to bridge the Atlantic for more than 2,000 miles with continuous land, but, being myself convinced that Palæozoic lands and seas were entirely different both in position and in trend from those of the present day, I see nothing unlikely in the existence of such a land area during the Cambrian period.

I do, however, protest against the hypothesis of a single trough formed by a geosyncline and extending from Norway to Alabama, a distance of nearly 4,000 miles. There is really no evidence on which to base such a piece of imagination, nor can I see any necessary connexion between the geographical extension of the Cambrian sea and the subsequently formed Caledonian system of flexures. An oceanic area is not necessarily a geosyncline, and even the North Atlantic of the present day comprises two troughs separated by a median ridge.

Finally, it seems possible to form some idea of the width of the sea space between the opposing shores of the Atlantic and Arctic continents of Cambrian time. Supposing its average breadth on the European side was equal to the distance from lat. 50, which touches the south of Cornwall, to the Faroe Islands; this is about 850 miles, which is double the average width of the Mediterranean, and is consequently quite a sufficient distance for the development of a considerable depth of water.

Hence, it is very probable that the marine inhabitants of the northern shore of the Cambrian Atlantic Sea would be different from those of the southern shore, and that such a broad expanse of comparatively deep water would prevent migration from one side to the other, especially if a strong current swept along the northern side from west to east and a return current set in the opposite direction along the southern side. The American character of the Scottish Cambrian faunas will thus be satisfactorily explained.

VI.—Two New Species of Cirripedia from the Tithonian of Stramberg, Moravia.

By Thomas H. Withers, F.G.S.

(PLATE XXIII.)

Dr. M. Remeš, of Olmütz, Bavaria, recently submitted to Dr. F. A. Bather for determination, a small suite of fossils collected by him from the Tithonian of Stramberg, Moravia. Among them were two Cirripede valves which Dr. Bather kindly handed to me for identification. These two carinal valves cannot be referred to any of the described species, and, since they differ much from each other in size and ornament, I have felt myself compelled to describe them as separate species. The specimens remain in the collection of Dr. M. Remeš, but reproductions are preserved in the Geological Department of the British Museum.

Systematic Position.—Although we have only two carinæ before us, it is possible, with some probability of correctness, to indicate their systematic position.

In the known species of *Archæolepas* the carina is very small, somewhat triangular in shape, and slightly expanded at the basal angles. The present carinæ, therefore, cannot with much confidence be referred to that genus.

It seems much more probable that they belong to the genus *Brachylepas*, rather than to *Pollicipes*. The genus *Brachylepas* was founded (1901)[1] to embrace a single species, *Pyrgoma cretacea*, H. Woodward (=*Brachylepas Naissanti*, Hébert, sp.),[2] from the Upper Senonian, but Dr. Woodward subsequently (1906)[3] referred to it the

[1] H. Woodward, "On '*Pyrgoma cretacea*', a Cirripede, from the Upper Chalk of Norwich and Margate": Geol. Mag., Dec. IV, Vol. VIII, p. 150, 1901.

[2] See T. H. Withers, "The Cirripede '*Brachylepas cretacea*', H. Woodward": Geol. Mag., Dec. V, Vol. IX, p. 321, 1912.

[3] H. Woodward, "Cirripedes from the Trimmingham Chalk and other localities in Norfolk": Geol. Mag., Dec. V, Vol. III, pp. 339–40, 1906.

species *Pollicipes lithotryoides*, Bosquet sp., from the Maestrichtian, and *P. fallax*, Darwin, from the Upper Senonian. With *B. fallax* in particular both the carinæ now to be described agree remarkably in general shape, structure, and type of ornament, so that, in the absence of more precise evidence as to the remaining valves, they may be referred provisionally to the genus *Brachylepas*.

Brachylepas (?) fimbriatus, sp. nov. Pl. XXIII, Figs. 1*a*, *b*.

Diagnosis.—Carina semi-cylindrical, strongly convex transversely, not carinated, with an almost straight basal margin. Ornamented exteriorly with about nineteen regularly-spaced, prominent, transverse ridges, extending almost straight across the valve, closely and regularly undulatory, having a goffered appearance, which is emphasized by the ridges being crossed by about eighteen rounded longitudinal ridges radiating from the apex; the growth-lines between the transverse ridges also form slightly-raised ridges.

Material.—A single well-preserved carina, somewhat broken at the apex, and embedded in a piece of hard red limestone.

Horizon and Locality.—Tithonian, Red Limestone: Stramberg, Moravia.

Description of Holotype.—Carina semi-cylindrical, widening gradually from the apex to the basal margin; slightly bowed inwards; strongly convex transversely, not carinated; basal margin almost straight, but in the earlier stages of growth there is a tendency for the transverse ridges to be convex near the margins and concave in the middle. Outer surface ornamented with about nineteen prominent transverse ridges, terminating each period of growth, and extending almost straight across the valve, the growth-lines between also forming slightly-raised ridges; these ridges are regularly and closely undulatory, and the main transverse ridges are steep-sided towards the basal margin, the steep sides being smooth. The transverse ridges are crossed by about eighteen rounded, longitudinal ridges, which are slightly less prominent than the main transverse ridges, and give to them a conspicuously goffered appearance. By the crossing of the transverse and longitudinal ridges the structure of the outer surface appears somewhat cancellated. Inner surface not exposed, but the apical portion probably projected freely to some extent.

Length of valve, *circa* 13 mm.; greatest breadth, 5·1 mm.

Brachylepas (?) tithonicus, sp. nov. Pl. XXIII, Figs. 2*a*, *b*.

Diagnosis.—Carina semi-cylindrical, strongly convex transversely, not carinated, with the basal margin slightly concave in the middle and convex at the sides. Ornamented exteriorly with several regularly-spaced, sharp-edged, transverse ridges, not undulatory, the sharp edges having a rather beaded ornament; the spaces between the transverse ridges are smooth.

Material.—A single large carina embedded in a piece of hard white limestone. The apex of the valve has been broken away, and the remaining portion of the valve is somewhat fractured, but the outer surface is well-preserved.

Horizon and Locality.—Tithonian, White Limestone: Stramberg, Moravia.

Description of Holotype.—Carina semi-cylindrical, widening gradually from the apex to the basal margin; slightly bowed inwards; strongly convex transversely, somewhat flattened at the sides, not carinated, basal margin slightly convex at the sides and slightly concave in the middle, which is more pronounced in the earlier stages of growth. Outer surface ornamented with several (twenty-four on the portion preserved) prominent, sharp-edged, regularly-spaced, transverse ridges, terminating each period of growth, the spaces between being smooth; these transverse ridges are *not* undulatory, and their sharp edges have a somewhat beaded ornament, which may possibly be attributed to obsolescent longitudinal ridging (about sixty bead-like prominences can be counted on one near the middle of the valve). Inner surface not exposed, but the apical portion probably projected freely to some extent.

Length, *circa* 22·4 mm.; greatest breadth, 11·6 mm.

Comparison with other Species.—*B.* (?) *fimbriatus* agrees in general form with the carina described as *B.* (?) *tithonicus*, sp. nov., and both valves are evidently of the same type. *B.* (?) *tithonicus* differs greatly in size, being more than twice the length of *B.* (?) *fimbriatus*; it differs also in having rather more steeply inclined sides, in the absence of longitudinal ridges, in the transverse ridges being straight and not closely and regularly undulatory, and in the spaces between the transverse ridges being smooth.

B. (?) *fimbriatus* approaches more closely to the carina of *Pollicipes rigidus*, J. de C. Sowerby,[1] from the Gault (Albian), especially to those examples that are more strongly ridged longitudinally, than to the other Jurassic species. *P. rigidus* is distinguished from *Brachylepas* (?) *fimbriatus* by its much finer ornamentation, particularly in the longitudinal ridges, which are very much finer and twice as numerous; the transverse ridges are less regular, and although somewhat undulatory, are not regularly and closely undulatory, neither have they the peculiar goffered appearance as in *B.* (?) *fimbriatus*. Moreover, the transverse ridges are sharp-edged, and the spaces between them are not tranversely ridged as in *B.* (?) *fimbriatus*.

B. (?) *tithonicus* resembles in general form the carina of the Upper Senonian species *Pollicipes fallax*, Darwin (now referred to the genus *Brachylepas* by Dr. H. Woodward). In *B. fallax*[2] the transverse ridges are not nearly so prominent or so regularly spaced, nor have they the beaded ornament on their summits as in *B.* (?) *tithonicus*; the transverse ridges are also much more strongly concave in the middle

[1] J. de C. Sowerby, Trans. Geol. Soc. London, ser. II, vol. iv, p. 335, pl. xi, fig. 6*, 1836; C. R. Darwin, Pal. Soc. Mon. Foss. Lepadidæ, p. 73, pl. iv, fig. 7, 1851.

[2] H. Woodward, Geol. Mag., Dec. V, Vol. III, p. 341, Figs. 5–7, 1906. This and subsequent references are to published figures of the carina of the different species, and are not necessarily the references to the original description of the species.

and convex at the sides than in *B.* (?) *tithonicus*, and this considerably alters the shape of the basal margin.

B. (?) FIMBRIATUS and B. (?) TITHONICUS, compared with other Jurassic species.

Archæolepas royeri,[1] P. de Loriol (Portlandian = Tithonian), and *A. redenbacheri*,[2] A. Oppel (Kimmeridgian), have quite small and thin-walled carinæ, and are readily distinguished from the above two species by their triangular shape and the absence of transverse ridges.

Pollicipes suprajurensis,[3] P. de Loriol (Portlandian = Tithonian), differs in the more rapidly widening carina, in the smaller transverse convexity, and in the pronounced convexity of its basal margin.

Scalpellum reticulatum,[4] J. F. Blake (? = *Pollicipes*), a Kimmeridgian species, differs in the more rapidly widening carina, in the smaller transverse convexity, and in the strong convexity of the growth-lines; the basal portion of the valve is broken.

Pollicipes quenstedti,[5] von Ammon (referred to *Archæolepas* by Zittel), of Kimmeridgian age, although ridged transversely, has not the prominent equally-spaced transverse ridges, and has a somewhat less acute apical portion.

Pollicipes ooliticus,[6] J. Buckman (Bathonian), differs in having a proportionately much wider base, and in the absence of prominent equally spaced transverse ridges.

P. (?) *lotharingicus*,[7] A. Méchin (Pliensbachian = Charmouthian), differs much in shape, being considerably narrower and more attenuated in the upper half of the carina. It differs further in the absence of prominent, regularly-spaced, transverse ridges, and particularly from *Brachylepas* (?) *fimbriatus* in the absence of longitudinal ridges.

EXPLANATION OF PLATE XXIII.

FIG. 1*a*. *Brachylepas* (?) *fimbriatus*, Withers, sp. nov. External view of carina. × 3 diam. Tithonian, Red Limestone: Stramberg, Moravia.
,, 1*b*. Side view of same.
,, 2*a*. *B.* (?) *tithonicus*, Withers, sp. nov. External view of carina. × 3 diam. Tithonian, White Limestone: Stramberg, Moravia.
,, 2*b*. Side view of same.

The figures in this Plate have, by kind permission of the Keeper, been copied from photographs in the Geological Department of the British Museum, taken by Miss M. B. Chapman.

[1] P. de Loriol, Mém. Soc. Linn. Normandie, vol. xvi, p. 20, pl. iii, fig. 1, 1872.

[2] A. Oppel, Palaeont. Mittheil. Mus. d. k. Bayer-Staates, Stuttgart, 1862, Bd. i, p. 116, pl. xxxviii, fig. 6.

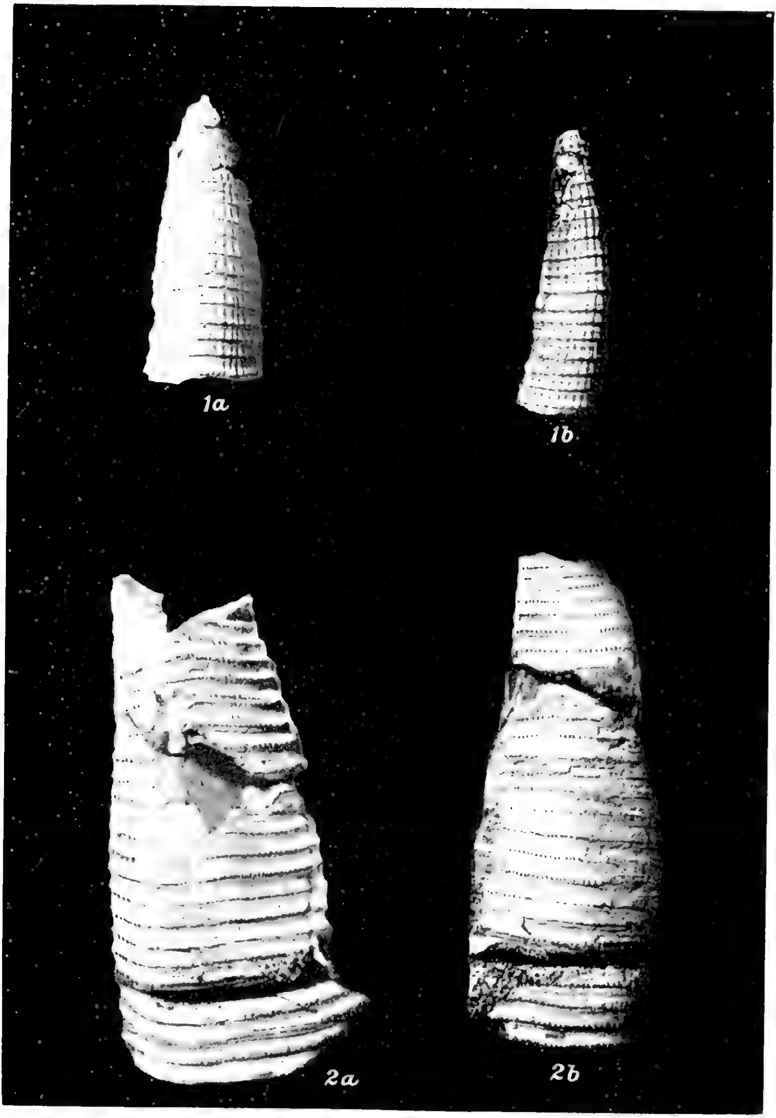
[3] P. de Loriol, Mém. Soc. Phys. d'Hist. Nat. Genève, vol. xxiii, p. 261, pl. i, fig. 1, 1873–4.

[4] J. F. Blake, Quart. Journ. Geol. Soc. London, vol. xxxi, p. 232, pl. xii, fig. 1, 1875.

[5] Max Schlosser, *Palæontographica*, Bd. xxviii, p. 60, pl. viii, fig. 11, 1881.

[6] C. R. Darwin, Pal. Soc. Mon. Foss. Lepadidæ, 1851, p. 50, pl. iii, fig. 2.

[7] A. Méchin, Bull. Soc. Sci. Nancy, ser. III, vol. ii, fasc. i, p. 16, with plate, 1901.



FIGS. 1*a*, 1*b*. *Brachylepas* (?) *fimbriatus*. FIGS. 2*a*, 2*b*. *B.* (?) *tithonicus*.
Tithonian : Stramberg, Moravia.

NOTICES OF MEMOIRS.

I.—Bembridge Limestone at Creechbarrow Hill, Isle of Purbeck.[1]

Report of the Committee, consisting of Professor T. McKenny Hughes (Chairman), Mr. H. Woods (Secretary), Dr. J. J. H. Teall, Dr. J. E. Marr, Professor E. J. Garwood, Mr. Clement Reid, Mr. W. Whitaker, and Mr. H. A. Allen, appointed to investigate the occurrence of the Bembridge Limestone at Creechbarrow Hill.

On the Results of the Further Examination of Creechbarrow Hill.

By Henry Keeping.

(*Abridged.*)

In September, 1910, I was sent by Professor Hughes to collect fossils on Creechbarrow, with a view to determining the age of the limestone which caps the hill, and I obtained a sufficient number of characteristic forms to enable me to refer the rock to the Bembridge Limestone. In the report then published[2] I further suggested that there was plenty of room for the rest of the Tertiary beds which might be expected to occur below the Bembridge Limestone, and I published a section in illustration of that view.

A grant from the British Association has since enabled me to ascertain, by means of excavations and borings, the nature of the strata along the flank of the hill.

The details thus obtained were as follows:—

Pit I (*the highest on the east side of the hill*).

		ft.	in.
(*a*)	Surface soil.		
(*b*)	Mixed clay and gravel with sharp angular flints	3	0
(*c*)	Blocks of hard limestone with *Melanopsis* and *Paludina* . .	2	0
(*d*)	Rubbly limestone. This I recognized as the same as the bed which occurs at the base of the limestone on Headon Hill, where it is rich in mammalian remains. I found here a tooth of *Palæotherium* on my last visit, and we now obtained a good tooth of *Dictulumus leporinus* (Owen)	0	9
(*e*)	Caking sand	3	6
(*f*)	Dark-brown sand	14	6
(*g*)	Light-grey sand with a very large flint at the base. This is on the same horizon as the bed in which Mr. Hudleston found the curiously coated flints which he thought were in situ and passed under the limestone	1	3
		25	0

Pit II.

		ft.	in.
(*a*)	Surface soil.		
(*b*)	Clay, sand, and gravel with fragments of weathered limestone at the bottom	16	0

[1] Report communicated to British Association Meeting, Dundee, September, 1912, Section C (Geology).

[2] Geol. Mag., Dec. V, Vol. VII, October, 1910, p. 436.

Pit III.

		ft.	in.
(*a*)	Surface soil.		
(*b*)	Dirty gravel	3	0
(*c*)	Caking sand	3	0
(*d*)	Large and small flints	1	0
(*e*)	Brown, stiff, sandy clay	3	0
(*f*)	Loose flint gravel	2	0
(*g*)	Black streaky clayey sand with flint-chips, concretions, and much manganese	7	0
(*h*)	Hard irony crust	0	3
(*i*)	Clayey sand with perished flints; one large white flint at the bottom of the hole	0	3
		19	6

Pit IV.

		ft.	in.
(*a*)	Vegetable mould	0	9
(*b*)	Clay, sand, and gravel with very large flints up to 1 cwt. This much resembles the Middle Headon Venus Bed	9	0
(*c*)	Drab sandy clay like that in brickyard; not bottomed	15	0
		24	9

Pit V (*about* 10 *feet below the summit on the west side of the hill*).

		ft.	in.
(*a*)	Surface soil.		
(*b*)	Clay with angular flints	2	6
(*c*)	Very stiff hardened clay with pieces of rubbly limestone containing much manganese and soot-like patches	9	6
(*d*)	Fragments of Bembridge Limestone very rich in fossils. This was where I obtained the chief collection made during my former visit. On this occasion we obtained a good spècimen of *Unio*, the first I believe, found at this horizon	2	0
(*e*)	Hard crumbling limestone	7	0
(*f*)	Sandy clay	9	0
(*g*)	Grey sands with quartz pebbles and broken flints. On my former visit I found a large fragment of Bembridge Limestone at a depth of 13 feet not far from this pit	4	0
		34	0

The lowest bed we touched was the drab sandy clay at the bottom of Pit IV, which is the same as that seen in the brick-pit, and the thickness of which I estimate to be not less than 40 or 50 feet. It seems to have been much used for dressing the land, and we found many old pits from which it had been obtained along the west side of the hill. This clay I regard as the equivalent of the Lower Headon formation. The coarse sand, which occurred above this, I take to be the Middle Headon Venus Bed, while the mottled red and green clays or marls which we found about 16 feet below the summit of the hill much resembled the Osborne Series.

Of the part of the hill explored by us I should say that about three-quarters consisted of Oligocene strata and the rest of sand and gravel. There is everywhere evidence of great disturbance of the strata, whether we refer this chiefly to large movements of faulting and overthrust, or the more superficial action of landslips, soil creep, etc.

[We are glad to print the important details of the Creechbarrow strata that have been obtained by Mr. Keeping, especially as they confirm the original discovery of our old friend Hudleston. (See Geol. Mag., 1902, p. 241; 1903, pp. 149, 197.)—Ed.]

II.—A THEORY OF THE MENAI STRAIT.[1] By EDWARD GREENLY, F.G.S.

RAMSAY'S view of the Strait as a glacial furrow was in the main accepted; but it was shown, from the general glacial phenomena and from soundings, that the middle reach of the Strait cannot be explained in that way. Evidence was adduced to show that this reach was excavated by glacial waters during the recession of the ice at a time when the mutual relations of the ice of the mountain-land and of the sea-basin admitted of the accumulation of a temporary lake. Post-Glacial erosion and subsequent changes of level have completed the bed of the Strait as it now exists.

III.—NOTE ON THE FISH-REMAINS COLLECTED BY MESSRS. R. CAMPBELL, W. T. GORDON, AND B. N. PEACH IN PALÆOZOIC STRATA AT COWIE, STONEHAVEN.[1] By R. H. TRAQUAIR, M.D., LL.D., F.R.S.

THE fish-remains from Cowie, Stonehaven, consist of :—

1. Small scutes which are about three times as long as they are broad, slightly convex on one side and correspondingly concave on the other, and apparently pointed at both ends. They seem to me to be referable to the category of Cephalaspidian scutes, only the external ornament, where visible, consists of longitudinal and slightly wavy striæ in place of tubercles. That the species to which they belong, as yet unnamed and undescribed, is pretty certain; but the advent of additional material is necessary before proceeding further in that direction.

2. Several fragments of thin minutely tuberculated plates, which may also be Cephalaspidian, though their nature, indeed, is still problematical.

3. Several specimens of a beautiful *Cyathaspis*, which I herewith dedicate to Dr. R. Campbell, and of which I give a brief diagnosis.

Cyathaspis Campbelli (Traquair).—Shield, ovoid, concave, shallow, broadest part situated behind the point of greatest expanse; covered with stout ridges running in a longitudinal direction, but also tending to converge a little anteriorly and posteriorly. These ridges are also constantly interrupted, so as to give almost a tubercular appearance, the tubercles being comparatively distantly placed, much compressed, and crenulated.

IV.—THE DOWNTONIAN AND OLD RED SANDSTONE OF KINCARDINESHIRE. By ROBERT CAMPBELL, M.A., D.Sc.

I.—*Downtonian.*

A THICKNESS of nearly 3,000 feet of vertical or highly inclined strata, formerly included with the Lower Old Red Sandstone, but now regarded as of Downtonian age, intervenes between Craigeven Bay and Stonehaven Harbour. Three groups of beds in this succession may be particularly noted :—

1. At the base of the series there is a thickness of about 200 feet of breccias interbedded with fine red mudstones and made up mainly of fragments of the underlying (?) Upper Cambrian rocks. The basement breccias rest unconformably on the (?) Cambrian. The unconformable junction, which is well seen on the north side of the headland at Ruthery Head, was formerly regarded as a line of faulting.

2. About 20 yards east of Cowie Harbour there occurs a thick belt of grey and greenish mudstones and shales which yield *Dictyocaris* in abundance. From this horizon have been obtained also *Ceratiocaris*; *Archidesmus* sp., and a new genus of Myriopod; (?) larval form of insect; *Eurypterus*, sp. nov.; fragments of scorpion; plant fragments and worm-tracks. Further, a thin bed of reddish sandy mudstone underlying the above series has yielded numerous plates of a new *Cyathaspis*.

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

3. About 60 feet below the *Dictyocaris* horizon there is a thickness of about 40 feet of volcanic conglomerates and tuffs, the presence of which implies that the volcanic activity, which was so marked a feature in the history of this area during the Lower Red Sandstone period, had already been initiated in Downtonian times.

Neither *Dictyocaris* nor *Ceratiocaris* has been found elsewhere in rocks younger than Upper Silurian, and, apart from the occurrence of tuffs, the lithological characters of the above succession recall at once the typical Downtonian rocks of the south of Scotland. The highest beds of the Downtonian pass conformably up into the micaceous sandstone and conglomerates of Stonehaven Harbour which may be considered as the base of the Lower Old Red Sandstone.

II.—*Old Red Sandstone.*

(*a*) *Lower.*—The Lower Old Red Sandstone Series consists of a great thickness of coarse conglomerates and sandstones with intercalated lavas and tuffs. Palæontological evidence is everywhere meagre, but the recognition of a number of well-marked volcanic zones has been of value in elucidating the structure of the area. The lavas include dacite, hornblende-biotite andesites, augite andesites, hypersthene andesites, hypersthene basalts, and olivine basalts. The tuffs are all acid in character. Minor intrusions of presumably Old Red Sandstone age occur in the form of dykes and thin sills of quartz porphyry, biotite porphyry, dolerite, and lamprophyre. The distribution of the lavas indicates that the centres of eruption lay along two lines—one to the east of the present coast-line, the other over the area of Dalradian Schists to the north of the Highland boundary fault.

The coarse conglomerates, which build up a great part of the succession, fall readily into two groups: (1) those in which boulders of quartzites or other 'Highland' rocks predominate; (2) those which are made up almost exclusively of volcanic rocks—volcanic conglomerates. Two points of particular interest may be noted in the former group—the occurrence of boulders of the 'Haggis rock' type of greywacké, and the abundance of boulders of the 'newer' granites, which have been collected even from the lowest conglomerates. The distribution of the volcanic conglomerates points clearly to the denudation of a thick series of rhyolites and acid andesites which must have extended far to the north of the Highland fault.

The chief structural feature of the Lower Old Red Sandstone area is a continuation of the well-known synclinal fold of Strathmore. In Kincardineshire, however, in the district to the west of Elfhill, there intervenes between the syncline and the Highland fault a steep-limbed anticline, pitching out to the south-west. The southern limb of the syncline is traversed by numerous powerful dip faults.

(*b*) *Upper.*—The Upper Old Red Sandstone occupies a small area on the coast in the neighbourhood of St. Cyrus. Although no fossils have been recorded, the lithological evidence—and particularly the occurrence of characteristic cornstones—leaves no room for doubt that here we are dealing with an outlier of the more extensive tract of Upper Old Red Sandstone of Arbroath. In Kincardineshire the Upper Old Red Sandstone is everywhere faulted against the Lower.

V.—On an Actinolite-bearing Rock allied to Serpentine.[1] By A. W. Gibb, M.A., D.Sc.

THIS rock is associated with the intrusion of basic rocks in Belhelvie, Aberdeenshire. Towards the northern end of this mass, which consists of troctolites, serpentines, and allied types, a rock is occasionally

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

met with which differs in some respects from the varieties common in the district. In its most typical development it shows a large number of dark green rounded spots set in a fine felt of paler green colour, full of glancing needles. Most of the specimens show a more or less clearly defined banding or schistosity. The affinities of the rock are somewhat obscure in hand-specimens. But under the microscope the dark spots are seen to represent olivine, which is still partly unaltered, but partly serpentinized, as well as granulitized and drawn out. The rest of the rock is largely made of actinolite in small crystal flakes; there are also present a green spinel, abundant magnetite, and sometimes other ingredients. In most varieties there is no trace of felspar. This rock passes into varieties in which the spots are much less obvious, and finally grades into a rock that might be described as an actinolite-schist.

The exposures of this rock, so far as they have been mapped, lie mostly on the outer fringe of the basic intrusion, and therefore close to the line of junction with the metamorphic rocks into which the igneous rocks have forced their way. From its field relations and its general characters it is clear that it represents a type of the basic rock which has undergone actinolitization on an extensive scale. The original rock from which it is derived must in most cases have been an olivine-enstatite rock, more or less completely serpentinized, or else a very basic troctolite. Although actinolitization is widespread in this, as in other metamorphic areas, a rock of this particular type has not been noted in this locality before. It has nowhere been found in large mass, and seems essentially a marginal phase. The most prominent exposure yet met with is, or was, a clump in a field adjoining the Udny Road, immediately south of 'Skelly-hill Wood'. This exposure has recently been entirely blasted away, and it seemed desirable to make a definite record of its occurrence.

VI.—THE ARCHÆAN ROCKS OF LEWIS.[1] By B. N. PEACH, LL.D., F.R.S., and J. HORNE, LL.D., F.R.S.

DURING 1911 the authors visited Lewis with the view of comparing its Archæan rocks, previously described by Macculloch, Murchison, Heddle, and James Geikie, with the types of Lewisian Gneiss mapped by the Geological Survey along the western seaboard of Sutherland and Ross. The areas examined comprised sections taken at intervals along the east coast from Tolsta Head, north of Stornoway, to near Loch Bhrollum, opposite the Shiant Isles—a distance of about thirty miles; and along the west side from the Butt of Lewis to Carloway—a distance of twenty-five miles. Traverses were made across the island (1) from Barvas on the west to Stornoway on the east, thence over the Eye peninsula to Tiumpan Head; and (2) from Carloway by Callernish to Keose on Loch Erisort, and Stornoway.

A large series of specimens was collected and submitted to Dr. Flett for examination, who has furnished a valuable detailed report showing wherein they resemble and wherein they differ from types described by Dr. Teall in the Geological Survey Memoir on *The Geological Structure of the North-West Highlands of Scotland* (1907). Dr. Flett has arranged the specimens in the following groups: (1) muscovite-biotite-gneiss, (2) biotite-gneiss, (3) biotite-hornblende-gneiss, (4) hornblende-gneiss, (5) pyroxene-gneiss, (6) hornblende-schist, (7) pyroxenite, (8) pegmatite-gneiss, (9) granite-gneiss, (10) mylonite.

In the various sections examined throughout the island, rocks belonging to groups (2), (3), and (4) are the main components of the Archæan

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

Complex. They are intimately associated with each other, and have a common foliation. The muscovite-biotite-gneisses (1) occur together with the biotite-gneisses, but they are not abundant. The pyroxene-gneiss (5) is recorded only from one locality, viz. Dalbeag, near Carloway, where it forms part of a basic mass which is cut by the foliated granite of Carloway (9). The hornblende-schists (6) constitute basic masses in the complex, with a foliation more or less parallel with that of the contiguous gneisses. The relative age of the members of this group has not been definitely ascertained. The pegmatites and pegmatite-gneiss (8) intersect the other components of the complex, but they are sparingly represented compared with the great development of these types on the mainland between Laxford and Cape Wrath. One example of pyroxenite (7) was obtained in the policies of Stornoway Castle. Mylonites (10) are typically developed in certain sections along the eastern seaboard between Tolsta Head and Loch Bhrollum.

In the areas examined, the north-west and south-east strike, referred to by Murchison, is not characteristic of the gneisses of Lewis. It is prevalent immediately to the west of Stornoway, but exceptional in other tracts. In this connexion the observations of Professor James Geikie in the Eye peninsula were confirmed. The dominant strike over extensive areas runs a few degrees east of north and west of south; in certain localities it is north-east and south-west, and in others nearly east and west.

The prevalent types of gneiss closely resemble those to be found on the mainland between Loch Laxford and Cape Wrath, without the great series of acid intrusions. The structure is coarsely granular, or granulitic, the mineral grains being rounded and not elongated. The range of rock types seems to be comparatively limited, for there is a marked absence, in the areas examined, of the pyroxene-gneisses with blue quartz, of pyroxene-granulites, and other basic and ultrabasic materials, which are so characteristic of the Fundamental Complex between Lochinver and Scourie on the mainland. The remarkable series of basic and ultrabasic dyke intrusions in the west of Sutherland has not been detected in Lewis.

The flaggy granulitic gneisses of the Butt of Lewis which appear to run southwards along the belt of high ground between Stornoway and Barvas are of special interest. In structure they closely resemble the Moine gneisses east of the Moine thrust-plane, but they differ petrologically from the rocks of sedimentary origin that form the Moine Series of the Geological Survey. The system of over-folding and the direction of the axial planes of the folds approximate to those found in the Moine rocks on the mainland.

The platy rocks or mylonites, noted by Macculloch, occur along definite lines of movement, trending a few degrees east of north and west of south. Actual thrust-planes have been detected, which are inclined to the south of east at low angles, as if the displacements had been in a westerly direction. Various stages in the development of mylonites from the acid and basic gneisses are represented.

VII.—The Origin of Kopjes and Inselberge.[1] By J. D. Falconer, M.A., D.Sc.

DETACHED hills, projecting crags, and isolated rocks are features of almost every landscape, and in the moister regions of the globe their origin has usually been correctly assigned to the ordinary processes of denudation. They may arise either through dissection of earlier

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

plateau-surfaces, as frequently in the case of detached flat-topped and pyramidal sandstone hills, or by the weathering out of the more resistant units where the surface is composed of rocks of different degrees of hardness, as in the case of escarpments and of detached crags and hills of igneous rock. The kopjes and island mountains of the warmer temperate and tropical regions are essentially of similar origin, but on account of the present climatic conditions being in many cases different from those under which they were formed, their actual mode of origin has given rise to considerable discussion. A striking feature of these kopjes and inselberge is that they rise at intervals from an apparently level or gently undulating plain, which in most, if not all, cases should be regarded as a former base-level of erosion. The typical kopjes of South Africa are of sandstone, shot with veins and dykes of igneous rock, which has given them the necessary power of resistance to the agents of erosion. The old crystalline regions of Africa, however, are dotted with domes and turtlebacks of granite and detached groups of granite hills, which represent the more resistant elements of the crystalline complex. Some of these isolated hills possess flattened caps of weathered rock, and it seems probable, therefore, that the sculpturing of the original crystalline surface was due, not so much to the direct erosion of the unweathered rocks, as to the effect of periods of elevation and erosion following upon periods of decomposition in situ at base-level. As the result of erosion a somewhat irregular surface would be produced, but a slight subsequent negative movement would suffice for the obliteration of the minor irregularities and the consequent accentuation of the less weathered portions of the surface. The repetition of such a cycle would lead to the increased prominence of the earlier hillocks and the formation of others of lower level. It has been suggested that a landscape with inselberge is of desert origin, but the various phenomena can be explained more readily as the result of weathering and erosion during successive small oscillatory movements of a regional character in the neighbourhood of base-level.

VIII.—The Heavy Mineral Grains in the Sands of the Scottish Carboniferous.[1] By T. O. Bosworth, B.A., B.Sc., F.G.S.

These observations were made at the commencement of an investigation which the author has now no opportunity to carry on.

The chief heavy grains are :—

Garnet, which, though in some sands practically absent, in others is in such excessive quantity as to almost mask the presence of other grains.

Zircon, always present, and sometimes the most abundant species.

Magnetite, always present.

Tourmaline, always present.

Rutile, always present, but varies widely in quantity and characters.

Staurolite, often present, but not plentiful.

Anatase, occasionally present in noticeable amount, as well-formed plates of steel-blue colour.

Barytes, found in a few cases in large amount. It is probably a cement, though well-formed crystal plates occur. Sandstones containing this cement are very hard. I find it in several building stones.

Characteristic of all the grains is their angularity. The garnets have the dodecahedral cleavage developed out in a remarkable manner,

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

so that the grains have elaborate zigzag shapes with innumerable corners and edges. The contrast between these heavy grains and those in desert sands is much more marked than in the case of quartz.

The heavy mineral contents prove the sands to belong to at least two entirely different kinds :—

(*a*) Sands in which the heavy mineral grains consist mainly or largely of garnets.

(*b*) Sands in which garnet is absent or scarce.

Vertical and Lateral Distribution.—The amount of evidence yet collected is only sufficient to be suggestive of the kind of results which may be obtained.

In the following list o denotes garnetiferous, × denotes non-garnetiferous. (Measurements in bore sections are actual, and are not corrected for inclined strata.)

Red Measures.		
o	Rutherglen.	
Coal-measures.		
o	Cambuslang	above Humph Coal.
o	Chapelhall, Shottsburn	24 feet above Lower Drumgray Coal.
o	Chapelhall, Shottsburn	just above Lower Drumgray Coal.
o	Chapelhall, Shottsburn	,, ,, ,,
o	Fauldhouse Quarry	above Crofthead 4 feet Coal.
×	Chapelhall, Shottsburn	below the Coals, faulted, and near Millstone Grit.
Millstone Grit.		
×	Bilston Burn, near Edinburgh	Roslin Grit.
×	Glasgow, Blochairn Quarry	above fireclays.
×	Muirhouse Bore, Lanarkshire	depth 30 feet.
×	Muirhouse Bore, Lanarkshire	depth 174 feet.
×	Levenseat	above Curdley Ironstone.
×	Balfour Bore, Fife	12 feet above Levenseat Limestone horizon.
o	Bilston Burn	6 feet above Castle Carey Limestone horizon.
Carboniferous Limestone Series.		
o	Balfour Bore, Fife	36 feet below Calmy Limestone horizon.
o	Bilston Burn	100 ,, ,, ,,
o	Balfour Bore	360 feet above Index Limestone.
×	Giffnock	270 ,, ,, ,,
o	Balfour Bore	150 ,, ,, ,,
o	Bilston Burn	12 ,, ,, ,,
o	Bishopbriggs, Hunters' Hill	just ,, ,, ,,
×	Kirkintilloch	40 feet below Index Limestone.
o	Linlithgow	200 ,, ,, ,,
×	Bilston Burn	540 ,, ,, ,,
×	Balfour Bore	798 ,, ,, ,,
o	Balfour Bore	1,242 ,, ,, ,,
×	Balfour Bore	1,374 ,, ,, ,,
o	Bilston Burn	5 feet below Hosie Limehouse horizon.
×	Bilston Burn	10 feet above North Greens Limestone.
Calciferous.		
×	Milngavie	above the Traps and below Hurlet Limestone.
×	Burntisland, Grange Quarry	about Burdiehouse horizon.
×	Hailes Quarry.	
×	Craigleith.	

Conclusions and Suggestions.—The sands containing such an extraordinary quantity of angular garnet have been derived from the Highland schists to the north and north-west of the basin, whilst the sands devoid of garnet are likely to have come from the north-east, east, or south.

It may be possible by a study of the heavy mineral grains and of the current-bedding, and the thickening and thinning of the beds, to subdivide the whole of the Carboniferous accumulation into a number of great lens-shaped or wedge-shaped bodies of sediment, which have been introduced from various directions and are interdigitated in a complex manner. These great lenticles might be expressible on maps, and might be helpful in explaining the lateral changes and the distribution of the coals.

IX.—A MULL PROBLEM: THE GREAT TERTIARY BRECCIA.[1] By E. B. BAILEY, B.A., F.G.S.[2]

THERE is in Eastern Mull a great breccia formation, with, in places, several intercalated rhyolite lavas. The breccia consists for the most part of an unbedded assemblage of blunted blocks and fragments of gneiss, granophyre, gabbro, and basalt, often associated with rhyolitic debris, for which latter a truly volcanic origin can be readily admitted. The problem is whether the non-rhyolitic material of the breccia has been derived through explosion or erosion. If the former alternative is adopted, many of the breccia outcrops must be regarded as marking the sites of volcanic vents, since in several cases the boundaries of the breccia are frankly transgressive. At the present time it is considered that the evidence favours an alternative view, that the breccia is an unconformable formation later than the basalt lavas of Mull, and that its transgressive relations are due to erosion which preceded and accompanied its formation. The basalt lavas of Mull have been violently folded into a series of anticlines and synclines, and it is in one of these synclines that the main outcrop of breccia in Eastern Mull is preserved, with every appearance, moreover, of approximate conformity to the surrounding basalts. Here it is difficult to escape the conclusion that the breccia is a thick layer overlying the basalts and folded with them. Alongside of the syncline is an abrupt anticline, in which are exposed all the rocks commonly recognizable as fragments in the breccia. The anticline has a core of gneiss, flanked locally by upturned Mesozoic sediments, and these by steeply dipping basalt lavas; intruded, chiefly into the gneiss, are granophyre and gabbro. Patches of breccia, distributed without reference to geological structure, occur in this anticlinal region, and rest upon or against all the rocks mentioned above. Although no positive conclusion can be drawn, it is suggested that the breccia has in large measure resulted from erosion, which operated during the period of upheaval of this and neighbouring anticlinal ridges.

X.—THE SEQUENCE OF VOLCANIC ROCKS IN SCOTLAND IN RELATION TO THE ATLANTIC-PACIFIC CLASSIFICATION OF SUESS.[1] By JOHN S. FLETT, M.A., D.Sc., F.G.S.

THE recognition of two great families of igneous rocks, the Atlantic and the Pacific, and their relation to certain types of earth-movement, which we owe to Harker, constitutes one of the greatest advances in rational petrology.

In Scotland we may take the Carboniferous volcanic rocks as typical Atlantic, while the volcanic rocks of Lower Old Red Sandstone age are characteristic of the Pacific group. We may add to the Atlantic two other series, the Permian or late-Carboniferous volcanic rocks of Ayrshire and East Fife and the nepheline-basalts (presumably Tertiary) of Caithness, with their associated camptonites and monchequites.

The Tertiary volcanic rocks of the Hebrides are Atlantic, and are associated with movements of Atlantic types. There is much reason in ascribing also to this period the north-west dykes, so abundant in Scotland, which contain not a few nepheline-bearing rocks.

The remaining volcanic rocks of Scotland are of distinct type. They comprise the Tayvallich lavas (perhaps pre-Cambrian), the Upper Cambrian volcanic rocks of the Highland border, and the Silurian (and

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

[2] With the permission of the Director of the Geological Survey.

Ordovician) lavas of the Southern Uplands. Pillow-lavas with keratophyres, etc., characterize this group. They are not connected with movements either of Atlantic or of Pacific kind, and may be placed in a special family.

XI.—On Buckled Folding.[1] By G. Barrow.

A NUMBER of descriptions have been published of portions of areas of regional crystalline metamorphism in which the dip of the bedding, or in some cases the dip of the foliation, is described as being at a low angle over a considerable area. These descriptions are at times so worded as to convey the impression that this represents the original and but slightly disturbed bedding of the altered sediments. Experience is gradually proving that the altered sediments in such areas are always intensely folded, and the detailed examination of the Highlands suggests that in place of these long-continued low dips being due to small disturbance, they really represent the most complicated form of structure, for which the name of 'buckled folding' is suggested.

The best-known illustration of the phenomenon in this country is afforded by the gneissose-flagstones or Moine gneisses. The deceptive nature of the dips in the rocks was soon recognized by the officers of the Geological Survey of Scotland, who found that in cliff sections the beds really ascended the cliffs by a zigzag course to which the term 'lightning-structure' was applied.

The mode of production of this 'zigzag' structure can be traced on the cliffs between Stonehaven and Muchalls, in Kincardineshire. The rocks in these cliffs consist of alternations of grits, gritty shales, and shales, becoming more and more crystalline as we proceed northward. Nearer Stonehaven the bands of grit may be seen to ascend the cliffs in an unbroken or unbent course from bottom to top, having a high dip in a northerly direction. The limbs of the folds are thus isoclinal and unbent. But as we proceed northwards the course of the grit bands up the cliff face is no longer straight; a small overfold or 'buckle' is developed on it. At first only one is seen in the whole height of the cliff; further north two occur; then three, and so on, till at last they are so close together that the still straight portion of the fold is little, if at all, longer than the 'buckled' or overfolded portion. If the upward course in the cliff of each grit band be carefully followed it will be found that the oncoming of this 'buckling' structure does not alter the dip of the band as a whole; it still descends at much the same angle, only it pursues a more zigzag course. The overfolds or buckles all face the same direction right up to Muchalls, and a little consideration will show that this 'buckling structure' must have been produced after the isoclinal folding was completed. There is thus no evidence to suggest that the rocks in which the buckling structure has been developed should be separated as a different series from those in which it does not occur. In the interior of the South-Eastern Highlands this structure is present in all but the southern margin of the area, till we reach the first outcrop of the Highland quartzite, where the buckling rapidly ends and the earlier isoclinal folding is left unaltered. For a distance of some seven or eight miles the buckling structure is either very rare or absent, but it sets in again in the quartzite close to Braemar. It is there also shown both by the marginal sandy beds, known as the Moine gneisses, and the dark schist next them. There also is no justification for separating the beds with the superinduced 'buckling structure' from those without it, as has been generally done. A key to the connexion between the 'buckled' and 'non-buckled' areas occurs in the ground about Shiehallion and to the north (Sheet 55, Scotland). At Shiehallion we have the quartzose beds forming the

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

margin of the quartzite, and containing the boulder bed and the limestone close by; further north we have the same group again. In the first case we have isoclinal folding; in the second, buckled folding, or Moine gneiss.

REVIEWS.

I.—The Permian Amphibia and Reptilia of North America.

THE recent appearance of three[1] very important works dealing with the fauna of the 'Permian' of Texas and the traces of that fauna which have been found in New Mexico, Pennsylvania, etc., enables us for the first time fully to appreciate its importance and its many remarkable features. Evidence has been recently accumulating to show that this fauna is really largely of Upper Carboniferous age. Williston has pointed out that the fauna is an isolated one, apparently developed quite out of touch with the rest of the world; and although Broom has shown that it is composed of fundamentally the same stocks as the Permian fauna of South Africa, there is no doubt that his general argument is correct.

It is a very remarkable group of animals which on a ground plan of very primitive structure have built up astonishing specializations, so much so that types like *Cacops*, *Dimetrodon*, and *Edaphosaurus* are amongst the most bizarre animals known. These animals, and many others, seem to exhibit all the features which usually occur in the last individuals of a race: they are phylogerontic, and it is improbable that they left any descendants.

The 'Texas' amphibia and reptiles are then in general precociously specialized examples of the early stocks which in South Africa slowly developed along many lines and gave rise to the mammalia amongst other groups. In the light of these ideas it is of interest to examine some of them in more detail. *Diplocaulus*, now nearly completely known, is an extraordinarily specialized type with an enormous flat head, much produced over the ears, with a slender body and very reduced pectoral limbs. Nothing like it is known elsewhere, but it seems to be a terminal member of the line of Microsauria represented by *Ceraterpeton* and *Diceratosaurus*, which occurs in Europe and North America.

The imperfectly known *Trimerorachis* is a rather unspecialized type, interesting because of its close similarity with the South African Upper Permian *Bothriceps Huxleyi*, now more completely known. The large and very well-known *Eryops* is a specialized representative of a type represented in Europe by *Actinodon*, and in South Africa by *Rhinesuchus* or *Myriodon*, a type whose structure as completely shown by specimens in the Pretoria Museum is thoroughly Eryopid, although much more generalized.

The extraordinary type *Trematops*, very reptilian in appearance, has no recognizable allies elsewhere, and the still more remarkable

[1] E. C. Case, *A Revision of the Amphibia and Pisces of the Permian of North America*, Carnegie Institution, Pub. 146, Washington, 1911; *A Revision of the Cotylosauria of North America*, Carnegie Institution, Pub. 145, 1911. S. W. Williston, *American Permian Vertebrates*, University of Chicago Press, 1911.

Cacops and *Dissorophus*, 'the Batrachian Armadillo,' break one of the diagnostic characters of their class by having a sacrum of two vertebræ. The rhinencephalic chamber of the former type is no doubt formed by a sphenethmoid, a bone which is shown without the least possibility of doubt in *Myriodon*.

The Cotylosauria, the most primitive of reptiles, are represented by a very large number of families and genera, all unique and many remarkably specialized. *Seymouria* is perhaps the most interesting of them; it has a skull which cannot be excluded by any definition which can be framed to include all types of temnospondylous amphibia, united to a body which in the loss of the cleithra and posterior coracoidal elements of the pectoral girdle is specialized, but which has only a single sacral vertebra! Four other types are represented by complete skeletons which show a very wide range of structure and adaptation, together with the preservation in some of them of primitive features, such as the wide ribs in the pectoral region which are so common in the large Stegocephalia.

Williston gives an admirably complete account of the structure of *Casea*, a new type represented by several skeletons found closely associated with *Varanosaurus* and *Cacops* in a bone bed unparalleled in the Permian of any other part of the world. Unfortunately the sutures in the skull are not visible, and its systematic position is still quite uncertain. *Varanosaurus*, represented by several skeletons in the same deposit, is of great interest. In its build and to some extent in its structure it is very reminiscent of the lizards. The group to which it belongs, the Poliosauridæ, is very well represented in the Texas fauna, and is regarded by Case, and, if I understand him rightly, by Williston as including primitive members of the Pelycosauria, the long-spined reptiles belonging, as Broom has shown, to the Therapsida, the group which includes the mammal-like reptiles so well known in South Africa. It is undeniable that they do show many resemblances to this order, but their differences in many important features are so great that it seems improbable that they can really be at all intimately connected with them. Examination of the only known skull of the European *Protorosaurus* and of the skeleton of that type shows no characters which are inconsistent with a close relationship between it and *Varanosaurus*, and a very similar little reptile occurs in the South African Permian. The further exploitation of this fauna and the completion of our knowledge of little-known types is the most interesting problem before the American fossil Herpetologists, and is now being continued by Professors Williston and Case with very great and deserved success.

II.—The Geology of the Districts of Braemar, Ballater, and Glen Clova. By George Barrow, F.G.S., E. H. Cunningham Craig, B.A., F.G.S.; with contributions by L. W. Hinxman, B.A., F.R.S.E. 8vo; pp. vi, 138, with 7 plates. Edinburgh, 1912. Price 2*s*. 6*d*.

THIS memoir is descriptive of the Scottish one-inch Geological Survey map, Sheet 65. A glance at the map, which is clearly and brightly colour-printed, shows that the area is made up almost wholly of Highland schists, and of large tracts of granite, including the great central mass of Balmoral Forest with Lochnagar, 3,552 feet. Smaller portions of ground are formed of diorite, lamprophyre, serpentine, etc.

Scattered irregularly about the area are glacial deposits of Boulder-clay, sand, and gravel; also much peat, which is "wasting away in many places, owing to the effects of the east winds in spring". Terraces of valley gravel border the Dee, which traverses the district by Ballater, Balmoral Castle, and Braemar.

The memoir is accompanied by some excellent views of rock structures, but neither map nor memoir contain any sections to illustrate the structure of the country. Even a section showing the profile of the ground, with the outcrops coloured near the surface, in the manner adopted by Jukes, would have been useful and instructive. To complete a section to sea-level would no doubt have been impossible even in diagrammatic form. Moreover, as the Director points out in his preface, the metamorphic rocks are so intensely folded and invaded by igneous intrusions of different ages, that the authors of the memoir, and their colleagues in adjacent areas, differ greatly with regard to the succession of the sedimentary schists (quartzites, limestones, etc.), and with regard to the origin and history of the stages of metamorphism. To the petrographical features of the area the main portion of the memoir is naturally given, and it includes an account of the cairngorms for which the northern granite masses are noted. The local search for stones, however, "has been discontinued for many years, the importation of cheap foreign stones from Germany and Brazil having practically killed the demand." It is noted that the limestones are rich in minerals, developed by thermal metamorphism, and well known to collectors. Very fine examples of glacial action are exhibited by the ice-scratched rocks, the moraines, and the other glacial gravels in the Dee Valley and its branches.

III.—Sur la Diversité Génétique des Montagnes Éruptions. By A. Stübel.

Translated from the German by W. Prinz and C. Van de Wiele. Bruxelles, Acad. Roy de Belgique, 1911. 4to; pp. 70, with plate and figures.

An introductory note explains that arrangements were made by the Académies Royales de Belgiques in 1903 for the publication in French of this paper by the late Alphonse Stübel. The matter was delayed, however, and meanwhile Professor Prinz, who had undertaken the translation, died, leaving his manuscript incomplete. Under these circumstances Dr. Van de Wiele has carried the work through.

The paper begins by pointing out that the great majority of volcanoes are extinct. From this the conclusion is drawn that volcanoes are supplied from strictly local magma-basins, and not from a unique central reservoir.

The next point submitted is that all volcanoes, whether active or extinct, are of comparatively recent, that is, of post-Cretaceous date. As this statement is likely to cause the reader unnecessary trouble it is unfortunate that it was not defined more precisely; thus it would have been preferable, in every way, merely to have pointed out that, during Tertiary times, volcanoes established themselves in many regions where previously, for long ages, there had been no trace of igneous activity. The pith of the argument, developed from this text, is that the initiation of a volcanic regime must be a very different affair from its continuation. Lyell's philosophy is discarded, and in its place we are asked to accept speculation of a kind not easy to test by direct observation.

It is claimed that the volume of magma emitted as lava or agglomerate during any particular eruption must be proportional to the resistance overcome during the eruption. The actual initiation of a volcano is therefore accompanied by a very extensive extrusion of magma. In fact Stübel regarded it as logically certain that volcanoes are in the main *monogène* structures, each resulting from the eruption which gave it its birth. That *monogène* volcanoes do exist is of course well known, since Monte Nuovo and other historical examples may be cited; the novelty of Stübel's position resides in his belief that volcanoes are all of them essentially *monogène*, though in certain cases their structure may be considerably modified and obscured by later *polygène* accretions.

Topographical considerations are exalted to the position of prime importance in deciphering the life-history of volcanoes. Thus an acute cone with a relatively small crater is regarded as the only form attainable by a *polygène* volcano. A flattened dome or cone on the other hand indicates a *monogène* structure. Such a dome or cone may arise either through a process akin to bubble-blowing, producing a mass with a liquid interior enclosed in a solid cracking crust, or else through the rapid superposition of lava-flow upon lava-flow, with or without intercalations of agglomerate. *Monogène* volcanoes built on this latter plan are supposed to have a comparatively flat stratification, and to owe their conical form merely to a gradual exhaustion of the subterranean reservoir in each individual case, and to the consequent curtailment of successive outpourings of lava. An interesting suggestion places the origin of the parasitic cones of Etna in the body of the volcano, and not in its almost exhausted deep-seated reservoir.

A *monogène* cone, arising in the manner indicated above, may not have a crater at all, but on the other hand it may have one of relatively immense size. An eruption having spent its force, and nearly or quite emptied its limited magma-basin, is frequently brought to a close by an episode of rapid retreat, and the unconsolidated material of the central part of the cone flows or tumbles back into the pipe and so leaves behind a gaping caldera. This supposed connexion between calderas and the *monogène* origin of volcanoes is the point most strongly emphasized by the author. His conclusions are supported by an appeal to the moon, where the caldera form of crater is typically developed. The regular recurrence of the phenomenon in this case does seem to favour some simple and uniform explanation such as is afforded by the theory of the *monogène* eruption; but one cannot forget the uncertainty as to whether lunar craters are in truth volcanic, not to mention the certainty that the gravitational conditions under which they originated must have been very different from those encountered on the face of the earth.

A large part of the paper is devoted to the classification and discussion of volcanoes on the principles outlined above. There are throughout abundant and well-executed illustrations.

E. B. Bailey.

IV.—Annual Report of British Museum.

British Museum (Natural History).—Reference is made in the British Museum Return for the year 1911 (H.M. Stationery Office, 1912) to the use of the site on the north of the Natural History Museum, and the following paragraphs are of considerable interest:—

"As a result of further correspondence and of several conferences between representatives of the Departments concerned, a settlement has been arrived at, under the terms of which the boundary of the Natural History Museum as adjusted in 1899 has been secured to the Trustees. By the settlement the demolition of the existing Spirit Building has been avoided, and accommodation for the Geological Survey and the collections at present in Jermyn Street will be provided on ground south of the boundary line of 1899. The buildings for the Survey offices and the collections (while communicating with the Science Museum) will be in connection with and form a part structurally of the eastward extension of the Natural History Museum, and will be so arranged as to fit that extension when it is eventually built. A Lecture Theatre, which will be under the control of the Trustees but available for joint use by both Museums, forms part of the scheme."

"The Trustees in assenting to provide this accommodation for the [stratigraphically arranged] Geological Survey collections believe that the arrangement will be of great advantage to students and others interested, since these collections will thus be continuous with the part of the Natural History Museum in which are arranged the Systematic Palæontological and Mineralogical collections."

We note also that this year the Swiney Lectures are to be delivered in December and January, instead of in November, and Dr. Jehu's subject is to be "The Record of Life as revealed in the Rocks".

V.—Cambridge County Geographies.—Two more volumes have reached us. One on Lanarkshire, by Mr. F. Mort (1910), has been unfortunately overlooked. It contains good descriptions of the physical features, with views of the Leadhills, the Falls of the Clyde, and a diagram illustrating the pre-Glacial channels of the river. There is a brief account of the geology, more particularly in reference to the Coal-measures, and illustrated by a view of fossil trees at Whiteinch, near Glasgow. The glacial drifts are described, but no reference is made to the fossil shells of the Clyde Valley Beds. Lead-mines, the gold of Clydesdale, the coal and oil-shale, are duly mentioned in the section on "Mines and Minerals"; and we are glad to see the name of A. C. Ramsay in "the Roll of Honour".

Radnorshire (1912), by Mr. Lewis Davies, is described as a pastoral county with many sheep-walks, with no coal, no sea-coast, and no river of commercial utility, but formed of valleys, moorlands, and a mountainous tract, known as Radnor Forest. Many good views of the physical features are given, including the great artificial lake of the Caregddu Reservoir in the Elan valley constructed for the water-supply of Birmingham. The geology relates almost wholly to Ordovician, Silurian, Old Red Sandstone, and Igneous rocks. Brief accounts of them, of glacial phenomena, of mineral springs, and stone quarries are given.

VI.—Brief Notices.

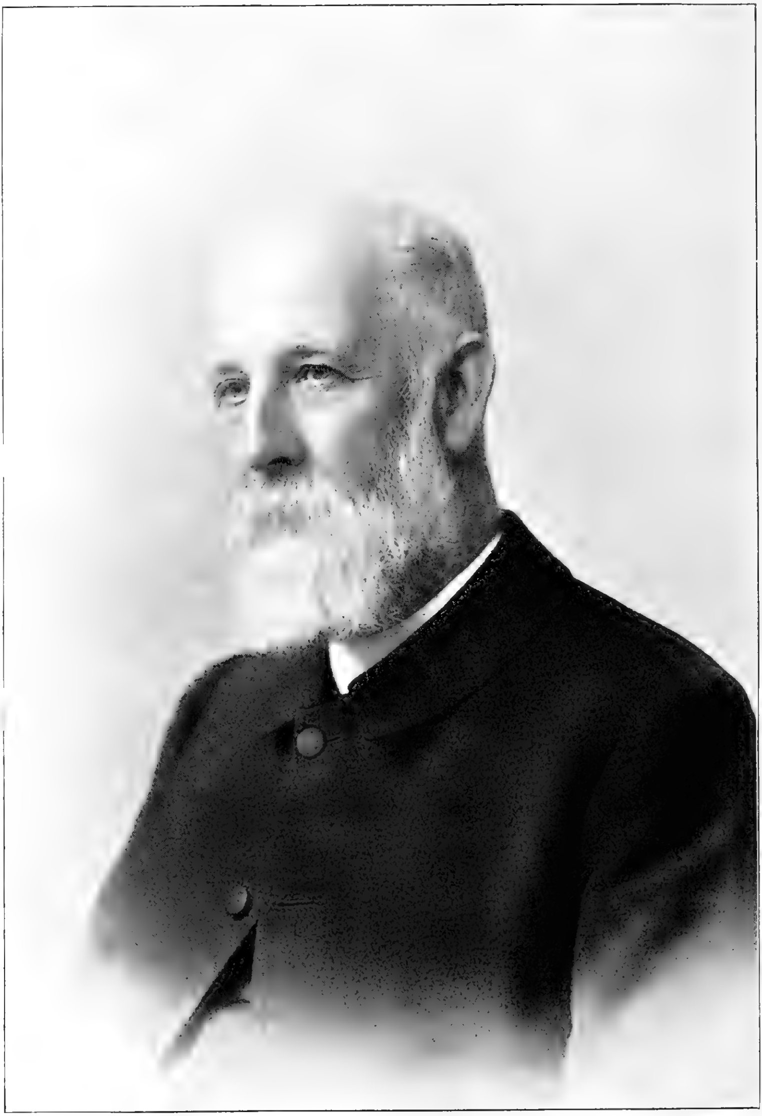
1. North of England Geology.—Some points of general interest are mentioned in a paper on "Lamprophyre Dykes in Long Sleddale, Westmorland" by Mr. Alfred Harker in the September number of *The Naturalist*. The bearing of these dykes is E.N.E., directly towards the Shap granite, 4 miles distant, and one peculiarity is the occurrence of numerous small spherical structures, the result of oozing-in of the final residual magma (wholly felspathic in composition) into steam-cavities. The same part contains a popular geological account of "The Evolution of Bridlington", by Mr. T. Sheppard, who contributes also an account of a lithographed map of South Yorkshire by William Smith, the "Father of English Geology". This map, dated 1819, and reproduced by Mr. Sheppard, has hitherto escaped record.

2. Geological Map of North America.—Under the title Geologic Map of North America the United States Geological Survey has published (dated 1911) a new and much improved edition of the map described by me in the Geological Magazine for 1906, p. 564. The price of the complete map in four sheets is 75 cents or 3*s*. carriage free. The scale is 1 : 5,000,000 or 78·9 miles to 1 inch. In the first edition only twenty-five divisions of rocks were shown. In the new edition forty-two divisions are indicated. Another improvement is the insertion of additional place-names, which enable one to identify localities better. Several of the blank spaces in the first edition are now geologically coloured, e.g. Nevada, Idaho, California, Arizona, New Mexico, Baja California, Yukon, and part of Alaska. One cannot help envying the Americans, whose Government, unlike our own, supplies such excellent maps at so low a price.—B. Hobson.

CORRESPONDENCE.

THE DEVONSHIRE CHALK CLIFFS.

Sir,—I recently spent four days running over the Devonshire chalk cliffs with the help of Dr. Rowe's admirable guide, and it seemed to me that he had not done quite full justice to those west of Branscombe Mouth.



The Rev. R. ASHINGTON BULLEN, B.A. (Lond.) F.L.S. F.G.S., etc.

He attributes all the flinty chalk seen to the west of the bluff in Branscombe West Cliff, described on p. 25, to the *Rhynchonella Cuvieri*-chalk, except for the tops of the first two or three bluffs. The latter are easily recognizable and all lie well to the east of the 'Camp' on Berry Cliff. But in the south-west face of the 'Camp', about 20 yards east of the cart track leading into the undercliff, there is a bluff quite 25 feet high accessible from top to bottom and composed exclusively of normal (flinty) *Terebratulina gracilis*-chalk, and there are four similar bluffs, first one by itself, and then three close together, in the cliff some way further west. Again, just east of the fence which runs down the cliff under Littlecombe Hollow there is a bluff which is probably continuous with two small exposures a few feet eastwards of it, the higher of which is composed of normal *T. gracilis*-chalk. The estimate of 60 feet of flinty *R. Cuvieri*-chalk, if based on the assignment to that zone of all the flinty chalk seen beyond Littlecombe Hollow, may therefore be excessive.

These exposures of *T. gracilis*-chalk are not expressly mentioned in the very full official account of these cliffs given in *The Cretaceous Rocks of Britain*, but it may be intended to cover them.

Incidentally I may add that the very curious *Metopaster cornutus* occurs in the flintless as well as in the flinty *R. Cuvieri*-chalk, though the reverse might have been expected.

R. M. Brydone.

27 Twyford Mansions, Marylebone Street, W.
October 9, 1912.

OBITUARY.

THE REV. ROBERT ASHINGTON BULLEN,

B.A. (Lond.), F.L.S., F.G.S., etc.[1]

Born June 11, 1850. Died August 14, 1912.

(WITH A PORTRAIT, PLATE XXIV.)

It is with sad regret we record the loss of our valued friend Mr. Ashington Bullen, who passed away suddenly on August 14, 1912, in his 63rd year.

Born at St. George's, Bermuda, on June 11, 1850, he had but a short acquaintance with his birthplace, his parents returning to England with their children when he was only 6 years of age. That he retained a love for his birthplace is shown by his making a special expedition to the Bermudas and subsequently publishing a very interesting account of the geology of the group (see Geol. Mag., 1911, pp. 385–95 and 433–42), very fully illustrated.

R. A. Bullen settled with his parents on the south coast and was sent to a private school at Gosport, where he received his early education,

[1] Mr. Bullen's death was recorded in the September Number of the Geol. Mag., p. 432.

and acquired a love for the sea and of Natural History which he never lost. It was originally intended that he should be prepared to enter the Civil Service, but by the force of circumstances he became instead a schoolmaster and continued his own studies privately, taking his B.A. in London University in 1873. He continued teaching after he was ordained in 1875; indeed, until 1883, when he became a curate. His first duty was at St. Peter's, Croydon (1875–9); thence he was transferred to Farleigh, Surrey (1879–80).

On December 19, 1855, Mr. Bullen married Miss Lloyd, daughter of Mr. Edward Lloyd, of Delahay Street, Westminster. He leaves his widow, one son, Robert Edward, and two daughters.

In 1883 he had the good fortune to be appointed curate to Archdeacon Farrar at St. Margaret's, Westminster, and held office until 1888, when he became Vicar of Shoreham, Kent, a preferment which he held until 1896. This was a peculiarly delightful period of Mr. Bullen's life, for it brought him into close personal contact and friendship with Sir Joseph Prestwich, who had for some years taken up his residence at Darent Hulme, Shoreham, Kent, an ideal country house for a man of science to retire to, after a long and active life. Here, for eight years, Mr. Bullen had the happiness of constant intercourse with one of the greatest geologists of the last century, and devoted many rambles over the Chalk Downs in search of flint implements and in discussing the age and extent of the old high-level gravels to which Prestwich devoted much of his latest years. In Lady Prestwich also Mr. and Mrs. Bullen found a most delightful and intellectual friend and neighbour.

From the influence of Sir Joseph Prestwich, Mr. Bullen took up and carried out a most valuable series of researches, which continued up to August last, in many localities where fossil land and freshwater Mollusca could be met with, and especially those associated with the remains of early Man, the early Plateau Gravels, the ancient prehistoric places of interment, and the implements of flint and bone identified with Palæolithic man. The titles of these papers are given at the end of this notice. Much of the spirit of scientific research, inspired by Prestwich, will be found embodied in the little volume on the prehistoric remains discovered at Harlyn Bay, which were very carefully figured and described by Mr. Bullen, a third and greatly enlarged edition of which appeared this year.

His papers on the Æolian deposits on the Coast of Étel; fossil Mollusca, Alcadia (Mallorca); on Manresa, Cataluña; and the Bermuda Islands (1911) specially merit attention.

Shortly after the death of Sir Joseph Prestwich (which occurred June 23, 1896) Mr. Bullen became Rector of Little Stukeley, Hunts (1898–9); and subsequently Rector and Vicar of Wisley, Pyrford, Surrey (1901–5). After resigning the living at Pyrford he made his home first at Hurstpierpoint, Sussex, and later at Englemoor, Heathside, Woking; devoting much time to the work of the various scientific societies to which he had become attached, and in travelling in France, Italy, Spain, and elsewhere.

The death of his second daughter (Miss Evelyn Bullen) in February, 1910, induced him to remove to Hilden Manor, Tonbridge. In 1912 he made a voyage to the Grand Canary, and was, indeed, contemplating a second voyage, with Mrs. Bullen, preparatory to publishing an account of the geology and fossil shells of those islands at the time of his death.

He joined the Geological Society in 1891, the Geologists' Association in 1893, the Malacological Society in 1897, the Linnean in 1899, and the Zoological Society in 1911. He was also a Fellow of the Royal Astronomical Society, and a member of the Selborne Society and the South-Eastern Union of Scientific Societies. It is to this last-named Society's Hon. General Secretary, Dr. Wm. Martin, M.A., F.S.A., that we are indebted for permission to reproduce the portrait (Plate XXIV) of Mr. Bullen which accompanies this notice.

An enthusiastic lover of Nature, an untiring worker, a faithful friend in time of need, his loss will long be felt by a very wide circle, to whom he was endeared by his unostentatious kindness and liberality.

List of Publications by the Rev. R. Ashington Bullen.

1894. "Shells from Portland Rubble Drift": Geol. Mag., pp. 431–2.

1898. "Fossil Non-marine Mollusca, Dover": Proc. Malac. Soc., pp. 162–5.

"The Authenticity of Plateau Implements": Nat. Sci., xii, pp. 106–11, pls. iv–vii.

1899. "Land-shells from Holocene deposit, Horseshoe Pit, Colley Hill, Reigate": Proc. Malac. Soc., iii, pp. 326–9.

1900. "Shells from Portland Rubble Drift": Geol. Mag., pp. 286–7.

1901. "Eolithic Implements": Geol. Mag., pp. 426–7; Journ. Vict. Inst. London, 1900, pp. 1–29, figs. and pls. i–vii; 1901, pp. 191–215.

Harlyn Bay and the Discoveries of its Prehistoric Remains. pp. 1–96, with 18 plates. 1st ed., 1901; 2nd ed., London, 1902; 3rd ed., Harlyn Bay, Padstow, 1912.

"Pleistocene Mollusca from Raised Beach Deposits, Perim Island": Proc. Malac. Soc., pp. 254–5.

"Note on Well-section at Dallinghoe (Suffolk)": Abs. Proc. Geol. Soc., 1900–1, p. 78; Q.J.G.S., lvii, pp. 285–7, 1901.

1902. "Notes on Holocene Mollusca from North Cornwall": Proc. Malac. Soc., v, pp. 185–8.

1903. "Eoliths from South and South-West England": Geol. Mag., Dec. IV, Vol. X, pp. 102–10, Pls. VI–VIII.

"Late Keltic Cemetery at Harlyn Bay (Cornwall)": Trans. S.E. Union Sci. Soc., 1903, pp. 1–6, figs.

"Pleistocene Non-marine Mollusca, Portland Bill, and Holocene Non-marine Mollusca from various localities": Proc. Malac. Soc., pp. 317–19.

1904. "New species of Non-marine Shells from Java and new species of *Corbicula* from New South Wales": Proc. Malac. Soc., pp. 109–11, pl. vi.

"New variety of *Planispira zebra*, Pfr., from the Island of Gisser, and new species of *Chloritis*, Java": Proc. Malac. Soc., pp. 191–2, pl. xi.

1905. "Notes on land and freshwater shells from the Alhambra Ditch, Granada, Spain; on recent land shells, Carmona, Province of Seville; and on land, fresh-water, and marine shells from Holocene deposits, Carmona": Proc. Malac. Soc., pp. 309–13.

"Pleistocene and Recent Shells from Crete": Proc. Malac. Soc., pp. 307–8.

Some materials towards the History of Wisley and Pyrford Parishes. pp. 80. Guildford.

1906. "Notes on some Microzoa and Mollusca from East Crete": GEOL. MAG., pp. 354–8, Pls. XVIII, XIX.

"Notes on a Holocene deposit at Harlton, Cambs": Proc. Malac. Soc., vii, pp. 85–7.

"Land and Fresh-water Mollusca from Sumatra": Proc. Malac. Soc., 1905, pp. 12–16, pl. ii; 1906, pp. 126–30.

1907. "On the advisability of appointing a Committee for the photographic survey of ancient remains in the British Isles": Rep. Brit. Assoc. Adv. Sci., p. 37.

1908. "Kitchen-Middens in North Cornwall": GEOL. MAG., pp. 140–1.

1909. "Holocene Non-marine Shells of Perranzabuloe": Proc. Malac. Soc., viii, pp. 247–50, 373–4.

1910. "Æolian Deposits on the Coast at Étel": GEOL. MAG., pp. 6–15, 97–101, Pls. IV and IX.

"Pitfalls for Elephants in Africa: in reference to Dewlish": GEOL. MAG., p. 334.

"Notes on (I) Pleistocene, (II) Holocene, (III) Recent Non-marine Shells from Alcudia (Mallorca), and (VI) Non-marine Shells from Manresa (Cataluña)": Proc. Malac. Soc., ix, pp. 118, 122.

1911. "Notes on the Geology of the Bermuda Islands": GEOL. MAG., pp. 385–95, 433–42, Pls. XVIII–XXIII, and Text-figs.

JAMES PARKER, HON. M.A. OXON., F.G.S.

BORN 1833. DIED OCTOBER, 1912.

WE regret to announce the death of Mr. James Parker, of Oxford, at the age of 79. In the leisure of a busy life as a publisher he devoted himself to archæological and geological studies, and accomplished much, especially in the geology of the neighbourhood of Oxford and in the exploration of the caves of Somersetshire. He made a great collection of fossils in the days when the Oolites round Oxford were extensively worked, and some of his finest specimens, including Teleosaurian skulls and Megalosaurian remains, were described in Phillips' *Geology of Oxford.* In 1880 he prepared a map and sections of the strata south of Oxford, which he printed with explanatory notes for an excursion of the Geologists' Association, and in 1884 he issued a revised edition of the same little work under the auspices of the Warwickshire Field Club. His exploration of the caves in the Mendip Hills was done in association with Professor Boyd Dawkins and the late Mr. Ayshford Sanford. Mr. Parker became a member of the Geologists' Association in 1861 and a Fellow of the Geological Society in 1867. He contributed a curiously critical paper on the valley of the Somme and its gravels to the Proceedings of the Association in 1875, and he frequently took part in the discussions at the meetings of both Societies. His views were usually original, not infrequently singular, and he appeared at his best in the informal debates during the excursions of the Geologists' Association, where his genial presence was always especially welcomed.

A. S. W.

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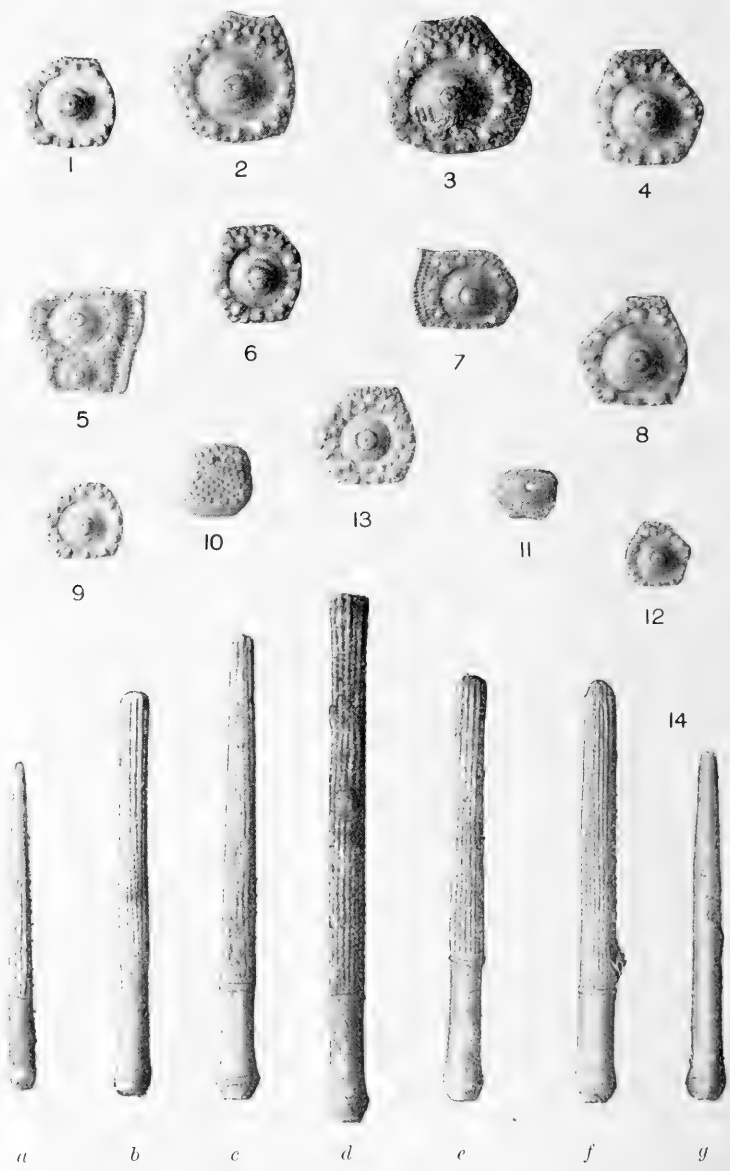


Cidaris faringdonensis, Wright.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE V. VOL. IX.

No. XII.—DECEMBER, 1912.

ORIGINAL ARTICLES.

I.—The Species of *Cidaris* from the Lower Greensand of Faringdon.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

(PLATES XXV AND XXVI.)

1. Introduction.

OF the varied Echinoid fauna from the well-known 'Sponge-gravels' of Faringdon, Berkshire, there are no constituent forms of which the remains are more abundant than those of *Cidaris*. It is no exaggeration to say that every handful of the 'gravel' will include many fragments of radioles, and some portions of test, which can be ascribed to that comprehensive genus.

The radioles seem to have been known to Llhwyd, although his mention of a "spine from Faringdon" may possibly refer to *Paracidaris florigemma* from the Corallian of the neighbourhood. It is, however, curious to find that, apart from references in lists of fossils found at the locality, these remains have been systematically discussed only by Wright (1868) in the monograph of *British Cretaceous Echinoidea*. In that work the species *C. faringdonensis* was first described, but the description and figures given were quite inadequate. This paper is an amplification of his description, based on very large quantities of material.

2. The name *C. faringdonensis*.

Wright spelt the specific name with a double *r*. It is true that on some old maps of Berkshire the name had this spelling, but long before 1864 it became usual to write it with the single *r*. I therefore prefer to follow Phillips, who in 1871 first changed the spelling to correspond with that of the name of the town.

As early as 1854 Sharpe (Q.J.G.S., vol. x, p. 194) remarked on the existence of more than one species of *Cidaris* in the Faringdon deposits, but until recently *C. faringdonensis* has been the only one recognized by name. In the report of an excursion of the Geologists' Association in 1909, Treacher gives a provisional identification of the radioles of the second type to *C. pretiosa*, Desor. Radioles of the same type are similarly labelled in the South Kensington Museum, but up to the present time no test fragments have been associated with them.

Having accumulated, largely owing to the constant help and encouragement of my friend Mr. Ll. Treacher, many hundreds of specimens of *Cidaris*-remains from Faringdon, I have been able to make an exhaustive comparative study of both types. There seem to be not more than two species of *Cidaris* represented among the very numerous fragments that I have seen, each species showing two fairly parallel varieties. (No account is taken in the present paper of the not infrequent waterworn radioles of *Paracidaris florigemma*, which have obviously been derived from the Corallian of the neighbourhood.)

I have examined Wright's type-specimens of *C. faringdonensis*, which are in the Museum of Practical Geology at Jermyn Street, and can confidently state that both the plates figured in the monograph (1864) belong to the same species. This is a contrary conclusion to that reached by Lambert (1892), but certainly, from a study of the figures alone, their reference to distinct species was justifiable.

Unfortunately the Cidarids of the 'Sponge-gravels' are almost always found in a disarticulated condition, and in no cases have the primary radioles and their tests been discovered in even probable association. Now the features of the radioles were well described and figured by Wright, while the treatment of the plates of the test was short and inconclusive. Judging by this fact alone, it would seem expedient to regard the species *C. faringdonensis* as having been founded on the radioles, in case it should be determined that the plates and radioles figured under that name belong to different species. Fortunately, in this case, there seems no doubt but that the plates of the type he figures on pl. ii, figs. 6 and 7 of the monograph, do in reality belong to the same species as the radioles of fig. 8. I have counted the actual numbers (of recognizable specimens) of plates and radioles of over a thousand specimens of both the types present at Faringdon, and find that the series corresponding with Wright's figures are almost twice as numerous as those of the second species. Adding to this the consideration that the average size of plates and radioles of the already figured types is much greater than that of the other forms, it seems to be a safe assertion that *C. faringdonensis*, Wright, is a valid species, of which both the test and radioles are known.

Of the other type, not without great hesitation, I have made a new species, the characters of which, as will be found in the description, are much more satisfactorily known than are those of *C. faringdonensis*.

3. Species that have been ascribed to *C. faringdonensis*.

In 1873 de Loriol, in the *Échinologie Helvétique*, p. 51, pl. iii, figs. 31–5, announced the discovery of *C. faringdonensis* for the first time out of England. Judging from his remarks, he seems to have referred only to Wright's description and figures in making the specific determination. The specimens he described are a broken test and some very fragmentary radioles. The latter certainly bear a considerable resemblance to the radioles of Wright's figures, although, as de Loriol himself observed, their collerettes are comparatively short. But when the description and figure of the Swiss test are compared with specimens of the true *C. faringdonensis* very obvious differences between the forms become apparent. One of the most readily recognized distinctions lies in the form of the test. Although not more than four plates of *C. faringdonensis* have been found connected together, all the evidence points to its having been large and tall, perhaps pyriform. De Loriol's specimen is quite small, and remarkably compressed at both poles. The existence of from five to six rows of granules in the widest parts of the ambulacra in the Swiss specimen finds no counterpart in even the largest examples from Faringdon. Although the absence or presence of crenelations on the interambulacral tubercles has little systematic value, yet the almost perfect smoothness of the platforms and parapets in de Loriol's specimen, and the persistent, and often very apparent, crenelation found in the species of the 'Sponge-gravel', lend a fresh point of contrast between the two forms. The 'granules très fins' of the scrobicular ring in the Swiss form do not correspond with the exceptionally large and spaced-out secondary tubercles from that region in *C. faringdonensis*, while a similar difference is found in the coarseness of the miliary granulation. On these grounds I feel confident that the *C. faringdonensis* of de Loriol is a distinct species from the *C. faringdonensis* of Wright, and should no longer bear the same name.

Almost twenty years later Lambert (Bull. Soc. géol. France, sér. III, tom. xx, p. 39), describing the Echinoid fauna of the Aptien of Grandpré, refers a Cidarid from that locality to *C. faringdonensis*; or rather, to the same species as that described by de Loriol. In the latter identification he would seem to have been correct, as his figures and descriptions agree in all essentials with those of de Loriol. It is, therefore, unnecessary to repeat the reasons that cause me to distinguish his species from the true *C. faringdonensis*. As a result of his study of the test-structure, Lambert doubtfully referred his species to *Goniocidaris*. Of the expediency or otherwise of this generic determination there is no need to inquire here, save to remark that sutural pits of the kind found in his species are well marked in many Oolitic (e.g. *C. marginata*, Goldf.) and Cretaceous (e.g. *C. sceptrifera*, Mant.) species. But there is not the slightest trace of such pits in the test fragments of *C. faringdonensis* from the typical locality, a fact which again emphasizes the difference between the two forms.

For this species, the *C. faringdonensis* of de Loriol (1873) and the *Goniocidaris faringdonensis* of Lambert (1892), I propose the name '*Cidaris*' *testiplana*, nom. nov., in reference to the extreme flattening of its test.

The only other reference of a fossil to *C. faringdonensis*, apart from stratigraphical lists, is that by Stolitzka (1873) in the *Palæontographica Indica*. Two very small fragments of poorly preserved radioles are doubtfully referred to this species. Since the descriptions and figures are as obscure as the specimens themselves, it is impossible to speak definitely as to the correctness of the determination. On prima facie evidence, it would be very exceptional for a species that characterizes a local deposit in England to occur also in India, and I am inclined to agree with Lambert (1892) that the identification is incorrect.

(PLATE XXV.)

4. Redescription of *C. faringdonensis*, Wright.

After these discussions it is possible to proceed to the diagnosis and description of Wright's species, followed by a similar treatment of the second type of Faringdon *Cidaris*. The synonymic list for the former includes all the references of a probably correct nature that I have been able to find.

CIDARIS FARINGDONENSIS, Wright (1864), 1868.

Synonymy.

1854. *Cidaris* sp., Sharpe, Quart. Journ. Geol. Soc., vol. x, p. 194.
1858. *C. coronatus*, Etheridge, Geol. Surv. Mem., Sheet 34, p. 32.
1861. *Cidaris* sp., Etheridge.
1864. [*C. farringdonensis*], Wright, Brit. Cret. Ech., Palæont. Soc., vol. i, pt. i, pl. ii, figs. 6–8.
1868. *C. farringdonensis*, Wright, loc. cit., pt. ii, pp. 68, 69.
1871. *C. faringdonensis*, Phillips, Geol. Oxford, p. 433, pl. xvii, fig. 5.
1874. *C.* ,, Davey, The Sponge Gravels of Faringdon.
1875. *C.* ,, Quenstedt, Petref. Deutsch., Echiniden, p. 179.
1877. *C.* ,, Davey, Cat. Foss. Cret. Berkshire.
1878. *C.* cf. ,, Barrois, Mém. Terr. crét. Ardennes.
1883. *C.* ,, Keeping, Fossils of Upware, p. 135.
1900. *C.* ,, Hesse, N. Jahrb. Min., Beil. Bd., xiii, p. 235.
1905. *C.* ,, Davey, Neocom. foss. Faringdon, p. 31.
1909. *C.* ,, Treacher, Proc. Geol. Assoc., vol. xxi, p. 119.
? 1863. *C. salevensis*, 'Desor,' De Loriol, Néocom. moy. Mont. Salève.
Non 1873. *C. farringdonensis*, De Loriol, Éch. Helvét., pt. ii, p. 51, pl. iii, figs. 31–5.
Nec 1873. *C. farringdonensis*, Stolitzka, Pal. Indica, Cret. Fauna, iv, p. 49, pl. vii, figs. 29, 30.
Nec 1892. *Goniocidaris farringdonensis*, Lambert, Bull. Soc. géol. France, sér. III, vol. xx, p. 39, pl. ii, figs. 3–12.

Diagnosis: Test, var. *typica*, nov.—Form unknown, probably large and considerably elevated. Ambulacra about one-sixth the width of the interambulacra, with two perradiad rows of prominent granules which rarely, even at the ambitus, enclose scattered smaller granules. Interambulacral plates thick; scrobicules circular, covering most of the plate-surface; bosses wholly or partially crenelated; mamelons large, perforated. Scrobicular circle of (usually thirteen) prominent secondary tubercles, separated by spaces wider than their diameters; with an outer, alternating, ring of tertiaries. Miliaries coarse, often only present towards the plate-angles.

Var. *maxima*, nov.—Similar to var. *typica*, but always of large size, with broad interambulacral miliary zones, in which the miliaries are closely packed, without apparent order.

Radioles.—Exceedingly long, cylindrical. Stem covered with longitudinal rows of small, partially confluent granules, of which alternate rows persist to the distal end, become carinate, and terminate in a slight corolla. Subsidiary granule rows often appear between the main series. Collerette long, often one-third the length of the radiole, smooth, and separated from the stem by a prominent, slightly oblique 'bourrelet'. Annulus prominent, base strongly developed. Acetabulum deep, with a crenelated margin and large central perforation.

Description: General Characters.—Except in a few cases all the portions of the test have been separated (often being waterworn), so that an accurate idea of the form of the urchin cannot be obtained. Judging from the very slight curvature of four associated plates of one column, and from the large dimensions of plates from the adapical part of the test, it may be inferred that the whole body was large and tall, perhaps somewhat pyriform. The diagnosis and description of the plates are generalized from over four hundred specimens, and of the radioles from nearly six hundred. The examples chosen for figuring show average types, among which may be included Wright's original figures.

The Apical System.—The genital plates (Pl. XXV, Fig. 10) are almost square in outline, the specimen figured measuring 4 mm. along the periproctal and radial margins. The thickness increases from the periproctal edge adorally, and at the coronal margin the plates are abruptly truncated. The genital pores are large and circular, placed at a distance of about one-quarter the radial diameter of the plates from the coronal edge. They pass obliquely through the plates, emerging in a slight concavity near the centre of their inner surfaces. The external ornament of the plates consists of granules on a shagreened surface. One row of granules, larger than the others, forms a rim between the genital pore and the coronal margin, while the rest are engaged in close-set lines, which tend to radiate from a point to one side of the pore. The plate-surfaces become smooth towards the edges, especially that which borders on the periproct.

The ocular plates (Pl. XXV, Fig. 11) are similar to the genital ones, except in shape. They are elongated transversely, and are strongly concave along the periproctal margin, being convexly rounded at the coronal edge. They too show a loss of ornament near the periproct.

The Corona: Interambulacral Plates.—Average-sized plates from the adapical surface of the test measure about 13·5 mm. longitudinally and about 10 mm. along the adoral transverse margin. The plates are constantly taller than broad, sharply incurved at the adapical end, scarcely curved in section in the other parts. The adapical transverse margin is a little inclined towards the interradial suture, and slightly concave. The adapical oblique margin is concave to a less degree, but the other three edges are sensibly convex. The adradial margin is strongly curved, concave adapically, but convex (concentrically with the scrobicular ring) in the middle and adoral parts. It is furrowed on the adradial surface by about twenty-four grooves. The scrobicule is wide, circular, slightly excavated, and situated towards the adoral region of the plate, near to the adradial margin. There is a definite basal terrace at about two-fifths the radial distance from the ring. The boss is central, rising like a dome to a platform of a diameter one-third that of the scrobicule. The platform is very slightly excavate, with a low parapet, which is in part rendered granular in appearance by more or less deep crenelations. There are about eighteen crenelations on the platform. The mamelon is large and prominent (diameter about 1 mm. less than that of the parapet), circular, with an undercut neck and deep central perforation. The scrobicular circle is complete, surmounted by a ring of from twelve to fourteen (usually thirteen) secondary tubercles. Their mamelons are about 1·5 mm. apart when their diameters are 1 mm. The diameter of a secondary may be as much as half that of the primary mamelon. The bosses of the tubercles are elliptical in shape, adjacent tubercles being contiguous in the direction of their long axes. Outside the scrobicular ring is a complete cycle of tertiaries, alternating regularly with the secondaries. (In small examples the tertiaries are without mamelons, but are always larger than the miliaries.) They are oval in shape, the pointed part encroaching a little into the scrobicular ring. They are usually less than half the size of the secondaries. Outside the tertiaries there appear, in very large specimens of var. *maxima*, traces of an intermittent ring of quaternaries, but these are not often distinguishable. The miliaries are closely packed, and diminish very little in size when traced to the margins of the plate. There are usually no miliaries between the scrobicular ring and the adradial and adoral margins of plates of var. *typica*. The granules are circular in plan, and somewhat flattened. They are always without any visible order of arrangement.

In some of the largest specimens (var. *maxima*), when an adapical plate may be as much as 27 mm. in transverse measurement, the miliaries are proportionately more numerous than on average-sized examples.

An interesting abnormality in a plate from this region is shown in Pl. XXV, Fig. 13. It will be noticed that the scrobicular ring is double, the accessory circlet of secondaries being inside the normal series and somewhat inclined towards the boss. There are thirteen tubercles in the normal cycle, and sixteen in the inner, accessory ring.

Plates from near the ambitus are often almost twice as broad as high, but otherwise differ hardly at all from those of the higher cycles. The crenelation of the platform is usually less pronounced. Both var. *typica* and var. *maxima* are as recognizable in this part of the test as in the others. Measurements of an average ambital plate of var. *typica* are: height 6·6, breadth 11·4 mm.

Towards the peristome the plates become almost square, so that the interradial suture will have been nearly straight. In rare cases the scrobicule tends to become elliptical, but it is usually circular. There are very few miliaries left on the plates near the peristome, even in var. *maxima*. It is of interest to note that two or three adoral interambulacrals are not frequently found in connexion. This is probably due to a more complete union along the sutures due to the pressure of the newly formed plates. The proximal adoral plate may show varying stages of resorption, the inward bevelling often commencing across a tubercle. The auricles are too much waterworn in all the specimens available to be worthy of description.

Ambulacral Plates.—There are, on the average, twenty-four simple primaries to each interambulacral. The pore-pairs are almost horizontal at the adapical end of the ambulacra, in deeply sunken poriferous zones, and become slightly inclined towards the perradial suture for most of their course. The pores are practically circular, and encircled by a faint peripodium. The pores of each pair are separated by a prominent granule of rather greater diameter than the pores themselves. Along the perradial part of the ambulacra high ridges of prominent granules, one granule to a plate, pass the entire length of the areas, and, except in very large specimens of var. *maxima*, occupy the extreme perradiad portions of the plates. In these large examples, near the ambitus, traces of irregular and quite minute granules occur, but these never reach half the size of the granules of the main series. The horizontal measurement of one ambulacral plate is about 2 mm., of which 1·2 mm. are occupied by the poriferous zone. Thus the total width of the ambulacrum is about 4 mm.—roughly one-sixth that of the interambulacrum.

Primary Radioles.—These radioles vary considerably in size, the largest obtained being 61 mm. in length and 4·25 mm. in breadth (some fragments indicate even larger size), while an average specimen gives corresponding measurements of 40 and 4 mm. The stem is cylindrical, never appreciably inflated, and covered with regular granular ridges. The space between the ridges is finely shagreened. The distal end of the stem is often slightly expanded, and alternate ridges, becoming carinate, develop into a stellate corolla of small size. The collerette is very long (the proportion varying but slightly with the length of the radiole), the average measurement being about 10 mm. Its diameter is very slightly less than that of the stem, and its surface is smooth. The 'bourrelet' which separates it from the stem is well marked, cylindrical, and almost at right angles to the axis of the radiole. The annulus is apparently smooth and not prominent. The base is inflated to about 1·5 times the diameter of the collerette, but the acetabular ring (which is often crenelated) forms a circle of diameter equal to that of the bourrelet. The acetabulum is deep, with a wide central perforation. Some radioles show a diminution in the diameter of the collerette near the bourrelet, making the proximal end of the radiole broader than the rest.

There are three or four large radioles in Mr. Treacher's collection which are smooth and tapering (Pl. XXV, Fig. 14*g*). I regard these as variants of *C. faringdonensis*. I have a specimen of *C. sceptrifera*, Mant., from the Upper Chalk, which has attached to it many normal denticulate radioles and several devoid of ornament; the smooth radioles from Faringdon seem analogous. They can be easily distinguished from radioles of *Pseudodiadema*, with which they are associated, by their greater proportionate breadth and general size. Some intermediate stages show faint traces of the typical *faringdonensis* granulation (cf. Pl. XXV, Fig. 14*a*).

Secondary Radioles.—I ascribe the larger secondary *Cidaris* radioles from Faringdon to this species. They are small and flattened, averaging 4 mm. in length and 1 mm. in breadth at the base. Their shape is that of a very acute isosceles triangle. At the abruptly truncated base is a shallow acetabulum. The convex (outer) side of the radiole is covered with fine, slightly granular lines (about seven in average specimens). The flat (inner) surface is quite smooth.

Comparison with other species.—The outstanding features of the test of *C. faringdonensis* are its great size, the coarse crenelation of the primary tubercles, the large size, but slight prominence, of the scrobicular tubercles, and the paucity and coarseness of the miliary granules. The characteristic features of the radioles are their length, the great development of their collerettes (and their separation from the stem by a bourrelet), and the faint corollæ at the distal ends. The distinction between this and the associated species will be dealt with after the description of that form. Apart from the species already discussed, there remains only one type with which comparison may be useful. The simple ambulacral granulation serves to distinguish *C. faringdonensis* from most Neocomian and Cenomanian species.

C. vesiculosa, Goldf., with which Wright compared the species, has notably broad miliary zones. Except in var. *maxima*, the miliaries occupy a very small part of the interambulacral plates of *C. faringdonensis*. The scrobicules in the latter species are shallow, in the former they are deep.

In the case of the radioles the peculiarities of *C. faringdonensis* mark it off sharply from other forms, except from a radiole described by de Loriol in 1863 as *C. salevensis*, "Desor in notis," 1862. This seems almost identical with the Faringdon radioles, but, since only a broken radiole of *C. salevensis* is known, I have thought it inadvisable to certainly identify it with *C. faringdonensis*, especially as it would necessitate a change in the nomenclature. The recognition of species of *Cidaris* founded on the radioles alone is quite impracticable, and merely complicates the already overburdened synonymy of many species whose structure is well known.

Horizon and Localities.—Aptian (Lower Greensand) of Faringdon, Berks; also from Upware, Cambs (*fide* Keeping), and perhaps from the Ardennes (*fide* Barrois).

(PLATE XXVI.)

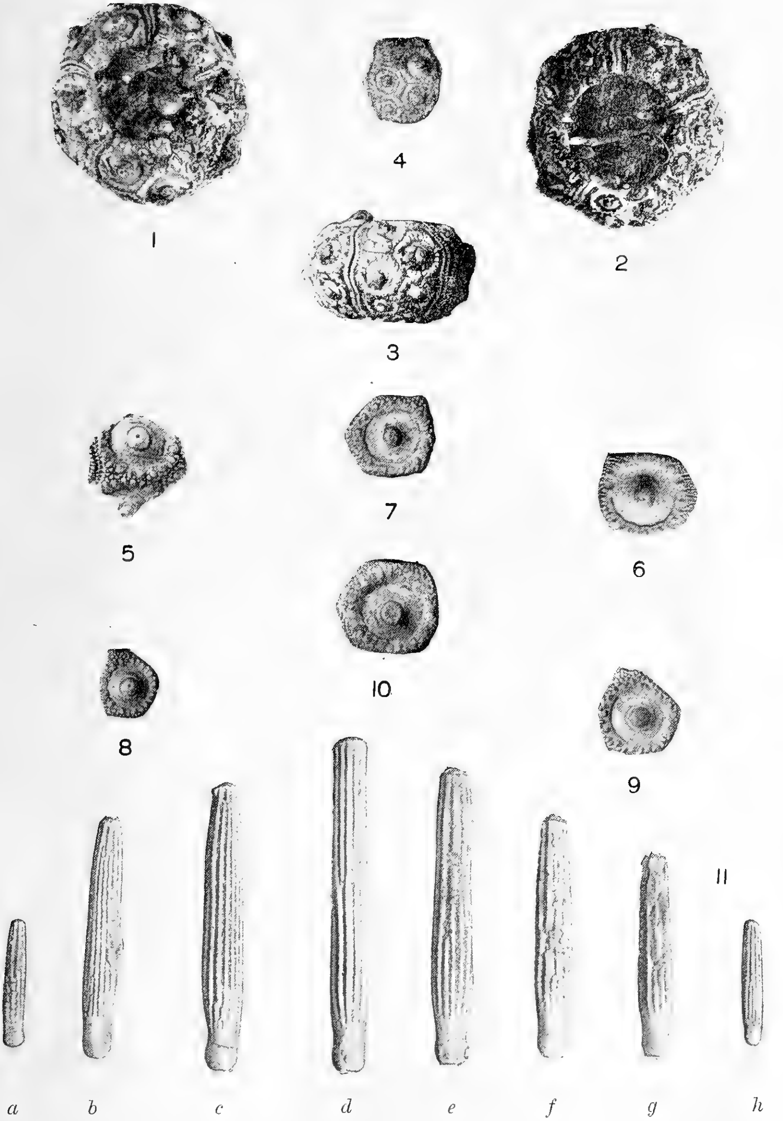
5. Description of the Second Species of Faringdon *Cidaris*, *Cidaris coxwellensis*, sp. nov.

(The 'Sponge-gravel' pits are near the village of Great Coxwell.)

Synonymy

1909. *Cidaris pretiosa*, Treacher (*non* Desor), Proc. Geol. Assoc., vol. xxi, p. 119.

Diagnosis: Test, var. *typica*, nov.—Form of medium size, fairly high, almost equally flattened adorally and adapically. Ambulacra about one-sixth the width of the interambulacra, with four rows of perradiad granules, the outer rows being the larger. Interambulacral plates thick, with obscure pits at the interradial angles and on the transverse sutures; scrobicules circular, bosses smooth, mamelons large, covering nearly all the platform, finely perforated. Scrobicular circle of very small, well-spaced secondary tubercles



Cidaris coxwellensis, Hawkins.

often joined to the scrobicular ring by a low ridge. Tertiary tubercles of almost equal size to the secondaries, alternating with them, and often intruding into their circle. Miliaries fine, rarely more than one row outside the tertiaries.

Var. *major*, nov.—Similar to var. *typica*, but constantly larger. Miliaries numerous, arranged in transverse series, separated by sulci on the ambital plates.

Radioles.—Long, cylindrical, inflated on one side. Stem covered with coarse, partially confluent granules (most marked on the inflated side), which increase in size gradually from the collerette until, near the distal end, they fuse into carinæ, terminating in a pronounced corolla. Collerette short, undefined distally. Annulus prominent, base large. Acetabulum deep, with a smooth margin and large central perforation.

Description: General Characters. — A very beautiful complete specimen has recently (1912) come into the possession of Mr. Treacher. It has many secondary radioles adhering to its surface, and remains of the apical system are preserved in situ. Since the surface of the plates is rather encrusted, it seems better to describe the structural details from other examples. There are several connected fragments of this species in Mr. Treacher's collection, and all offer identical characters. They all represent rather small specimens of var. *typica*, but otherwise agree perfectly with the abundant isolated plates of both larger and smaller size. The complete specimen is the holotype. The original of Pl. XXVI, Fig. 11*e*, is the type of the radiole. The diagnosis and description of the species are generalized from over 200 plates and a far greater number of radioles. In case it should be shown that the fragments do not all belong to the same species, the name *coxwellensis* should be applied to the test.

The complete corona is somewhat depressed in shape. The diameter of the holotype is 25·5 mm., and its height 16 mm. The average size would seem to be about one and a half times as great as this, judging from the dimensions of the isolated plates.

The Apical System.—One or two fragments of both ocular and genital plates occur in the holotype, but their characters, beyond that of a fine superficial granulation, are not well shown. The diameter of the apical disc is smaller than that of the peristome (12 mm. as against 13·2 mm.).

The Corona: Interambulacral Plates.—Average adult specimens of var. *typica* from the adapical region measure about 8·3 mm. longitudinally and 7·1 in their greatest breadth. The outline of the plates is thus proportionately taller than those of *C. faringdonensis*. The scrobicule is wide, circular, shallow, and near the adoral margin of the plate. The basal terrace is obscurely visible. The boss is central, often concave in section, sometimes dome-like, rising to a platform with a diameter less than a third the width of the scrobicule. The platform is practically flat, with no parapet, and is entirely uncrenelated. The mamelon is very large, of equal diameter with the platform, which is only visible under the undercut neck of the mamelon. The central perforation is relatively small. The scrobicular circle is complete, surmounted by thirteen or fourteen secondary tubercles. These are separated from one another by spaces often twice as wide as their diameters. They are feebly developed, often hardly distinguishable from the miliaries, especially as they are set well back from the rim of the scrobicule. There is often a low ridge stretching radially from the rim to the tubercle. Outside the scrobicular circle, but often encroaching into it, is a complete cycle of tertiaries, often guttate in shape, with the prolongation separating the secondaries. There is very little difference in size between the secondaries and tertiaries. The miliaries are very small, and only one or two occur on plates of var. *typica*. They are fairly numerous, but still minute, in var. *major*.

Plates from the ambital region are slightly broader than high. The scrobicule is slightly to the adoral side of the centre. Apart from the miliaries, the plates agree in character with those from the upper cycles. The miliary zone is not appreciably increased in importance in var. *typica*, but in plates of var. *major* it is quite broad, and the granules are arranged in roughly horizontal lines, starting with the tertiaries, the lines being separated by distinct sulci. This is a very obvious feature, and *C. coxwellensis* is one of the earliest species to show the character. Measurements of an average plate from this region are: var. *typica*, height 7, breadth 7·2 mm.; var. *major*, height 9·2, breadth 11·3 mm.

As in *C. faringdonensis*, the scrobicule often assumes a slightly elliptical outline near the peristome. The miliaries dwindle in size and numbers until they are practically absent on the adoral plates. The auricles are too poorly preserved to merit description.

Ambulacral Plates.—There are about nineteen ambulacrals to one interambulacral at the ambitus. The poriferous zone occupies more than half the width of each plate. The pores are separated by a prominent granule. On the non-poriferous part of each plate is one very prominent granule (not quite reaching the level of the interambulacrals) which is usually accompanied by a much smaller granule on the perradiad margin of the plate. The ambulacra have, therefore, four rows of granules, of which the outer rows are the largest. This applies to the smallest as well as the largest specimens examined.

The Primary Radioles.—These are very like the radioles of *C. pretiosa*, Desor. They are fairly long, but the length is somewhat counter-balanced by the breadth. Average radioles measure 38 mm. in length, and 5 to 5·5 mm. in greatest breadth. The stem is tumid, especially on one side, and is ornamented by rows of prominent, rounded granules, which are best developed on the tumid side. There are rarely any rows of granules which do not pass along the entire length of the stem. In some forms the granules are fused into denticulate carinæ. At the distal end there is a well-marked corolla. The collerette is very short, and not defined at its junction with the stem. The base is often wider than the broadest part of the stem, and the acetabulum is wide. The rim of the acetabulum is always smooth.

The Secondary Radioles.—These are very like those described for *C. faringdonensis*, but are always smaller. Those on the holotype show that the striations on the outer surface become specially prominent towards the distal end.

Comparison with other species.—The outstanding features of the test of *C. coxwellensis* are the smoothness of the platforms and great size of the mamelons of the primary tubercles; the minute size of the scrobicular tubercles; and the paucity of the granulation (except in var. *major*, where the miliaries are horizontally arranged). The main characteristics of the radioles are the coarseness of their granulation, the inflation of one side of the stem, and the shortness and undefined limits of the collerette.

A comparison of the above summary of the characters of *C. coxwellensis* with that given for *C. faringdonensis* will be sufficient to show the extreme contrast existing between the two Faringdon species. Even a fragment of a plate or a section of a radiole are sufficient to distinguish to which form they belong.

The slight development of miliaries on the interambulacra of *C. coxwellensis typica*, and their linear arrangement in var. *major*, are characters which separate the species from practically all Neocomian and Cenomanian types. When the large development of the mamelon and the feebleness of the scrobicular tubercles are taken into account, a still more thorough distinction is seen. Perhaps it is with *C. pretiosa*, Desor, that the new species has most affinity. A comparison with that species is natural, owing to the extreme similarity of the radioles in both forms. However, in *C. pretiosa* a very anomalous feature in the ambulacra—that of a small outer, and large inner, row of granules in the interporiferous area—is a sufficient contrast from the definitely inverse proportions of the similarly placed granules in *C. coxwellensis*.

The radioles are very like those of *C. pretiosa*, differing from them only in the more marked corolla developed at the distal end. In view of the great abundance of radioles of *C. coxwellensis*, and the complete absence of any test fragments referable to *C. pretiosa*, it seems clear that this similarity of the radioles is no criterion of specific identity. In fact, since the radioles found on one specimen of a *Cidaris* may vary from one another very profoundly, it is natural that the converse condition of similar radioles in different species should occur.

Horizon and Locality.—Aptian (Lower Greensand) of Faringdon, Berks.

6. Undetermined Fragments.

Considerable numbers of jaw-fragments, chiefly hemipyramids and teeth, occur in association with the other *Cidaris* remains in the 'Sponge-gravels'. They are usually waterworn, but the measurements of the pyramids, and their large size, indicate that they belong to *Cidaris*. The smaller fragments probably belong to *Pseudodiadema* and *Peltastes*.

In conclusion, I wish to express my gratitude to Mr. Ll. Treacher for placing his unrivalled collection of Faringdon Echinoids at my disposal for the purpose of the foregoing description; and to

Mr. A. H. Malpas, of University College, Reading, for photographing the specimens.

EXPLANATION OF PLATES XXV AND XXVI.

Plate XXV: Cidaris faringdonensis, Wright.

Fig. 1. Paucigranulate plate from adapical cycle (var. *typica*).
,, 2. Average plate (same cycle) of var. *typica*.
,, 3. Multigranulate plate (same cycle), var. *maxima* (type).
,, 4. Intermediate form (var. *typica*) between Figs. 1 and 2.
,, 5. Two associated plates from near peristome (var. *maxima*), showing elliptical scrobicules.
,, 6. Mid-zone plate of var. *typica*.
,, 7. Plate from upper part of test (var. *typica*) with half an ambulacrum attached.
,, 8. Exceptionally high plate (adapical cycle) of var. *typica*.
,, 9. Adapical plate of small specimen.
,, 10. Genital plate (probably referable to *C. faringdonensis*).
,, 11. Ocular plate (probably referable to *C. faringdonensis*).
,, 12. Smallest plate found.
,, 13. Abnormal plate with two cycles of scrobicular tubercles.
,, 14. Radioles: (*a*) waterworn at distal end; (*b*) average specimen with rudimentary corolla; (*c*) showing proximal end unworn; (*d*) largest radiole found; (*e*) somewhat thick radiole; (*f*) regularly cylindrical form; (*g*) entirely smooth radiole, a variant, not due to erosion.

All the figures are reproduced at about 1¼ times natural size.

Plate XXVI: Cidaris coxwellensis, n.sp.

Fig. 1. The type, adapical view (var. *typica*).
,, 2. The same, adoral view.
,, 3. The same, lateral view.
,, 4. Segment of small specimen (var. *typica*).
,, 5. Connected fragment, showing ambulacrum (var. *typica*).
,, 6. Type of var. *major*, showing sulci between the miliaries.
,, 7. Plate with characters intermediate between var. *typica* and var. *major*.
,, 8. Tall adapical plate (var. *typica*).
,, 9. Average adapical plate, showing smooth parapet and small scrobicular tubercles (var. *typica*).
,, 10. Somewhat eroded plate of var. *major*, showing broad miliary zone.
,, 11. Selected radioles: (*a*) from adoral surface, rough side of radiole; (*b*) from higher region, smooth side; (*c*) from similar region, rough side, showing unequal inflation and rudimentary corolla; (*d*) longest complete radiole found, very little inflated, rough side; (*e*) radiole constricted towards distal end; (*f*) similar to (*b*), but showing rough side; (*g*) similar radiole, with proximal end well preserved; (*h*) similar to (*a*), but showing smooth side.

Fig. 3 is of the natural size, all the others are 1¼ times natural size.

II.—Post-Jurassic Earth-movements in South Africa.

By E. H. L. Schwarz, Professor of Geology, Rhodes University College, South Africa.

Mr. BULLEN NEWTON has recently determined the fossils found by my students and myself in the Alexandria Beds near Port Elizabeth to be of Mio-Pliocene age; the full memoir will shortly be published in the Records of the Albany Museum, Grahamstown. Hitherto the Alexandria Beds have been regarded as Danian on the strength of the evidence afforded by the Polyzoa and casts of Lamellibranchs, but the well-preserved shells on which Mr. Newton founds his determination of the age of the beds leave no doubt but that this earlier one is wrong. If the beds had been Danian there should be some connexion between these and the Pondoland Cretaceous in regard to the conditions of their deposition, which there is not. In trying to clear the way for a better conception I endeavoured to show that as the affinities of the Pondoland fossils lay with Cenomanian forms from Tunis, the age of the Pondoland Beds was towards the lower half of the Upper Cretaceous; then the supposed Cretaceous beds of Alexandria with Tertiary sharks' teeth would represent transition beds between the Cretaceous and Eocene. Dr. Kitchin, however, objected to this, as the Pondoland fauna taken as a whole was Turonian, if not Senonian, and the gap between the Pondoland and the Alexandria Beds became so small that there was not time for the undoubted changes in the land to have taken place which would have allowed the deposition of these several formations in the positions we now find them. The Pondoland, like the Uitenhage, Cretaceous beds belong to a period of sinking in the continent of Africa, at least as far as the southern and eastern portions are concerned, whereas the Alexandria Beds belong to a period of uplift. Mr. Newton's new determination, therefore, solves the problem; there are many other important considerations bound up in this matter. There is the question of the connexion of Africa and South America and perhaps Australia, in Tertiary times, to account for the distribution of the Proteaceæ among plants and many peculiar freshwater fish, for example, the Dipnoi, Chromididæ, and Characinidæ, among animals. There is also the question of the fragmentation of the Indo-African Continent, which is the explanation of the straight coastlines on the western side of the Peninsula of India, on the eastern side of Madagascar, and on the south-eastern corner of South Africa, as on this theory they represent fault-scarps. There is, again, the puzzling problems of the submarine features in the Indian Ocean, such as the level-topped, straight-edged plateau on which the Laccadive and Maldive Islands rest, that has been cited as evidence for the existence of submarine erosion, but which reminds one of a fault-block in Utah. All these points receive new light from the determination of the Alexandria Beds to be of Mio-Pliocene age, and I have thought it of interest, therefore, at this stage to piece together as far as is possible from our present state of knowledge the facts such as we know them in South Africa, and to draw from them a connected account of what movements went on in this part of the earth's crust.

We begin the story with the deposition of the Cape and Karroo formations, that is, of strata ranging in time from the top of the Silurian to the Trias. The two lower series of the Cape formation are marine, but in the uppermost series, the Witteberg, the Karroo Lake had already been enclosed by land and had become fresh, as witness the large amount of coaly material found in the beds and the delicate stems of the Bothrodendra with leaves attached, which could not have stood the action of the waves in the open ocean. The southern margin along which the shallow-water formation, the Table Mountain Sandstone, was deposited was not very far from the present shore-line ; it was formed by the strand line of a prolongation of the Madagascar ridge. In early Cape times between this ridge and the rest of Africa there was a narrow strait, which became broader and deeper in Bokkeveld (Devonian) times, and was finally enclosed in Witteberg (Carboniferous) times. The succeeding Karroo rocks were laid down in this lake, having for a northern margin a line running through Prieska and the Southern Transvaal and a southern shore along the old Madagascar ridge. The Karroo sediments were laid down throughout in shallow water, ripple-marks being common throughout, but as they are some 15,000 feet thick, the floor on which they rested must have been continuously sinking.

The original floor of the Karroo Lake was thus bowed down by the weight of the ever-accumulating sediments, implying a very great height of and enormous denudation on the land now situated in Bechuanaland and the northern part of the Transvaal, and also of the old Madagascar ridge. The underlying rocks also participated in the downward movement and were in tension owing to the stretching due to the sinking. Into the cracks formed from this cause molten rock began to creep and gradually forced its way upwards, riddling the Karroo sediments with a plexus of dykes and sills of dolerite of so close a texture that one may regard the whole series of intrusions as constituting a single gigantic laccolite of the cedar-tree type.

The heat of the lower layers of the earth's crust had now become transferred to the upper layers by these intrusions of dolerite. The Karroo sediments, becoming heated, expanded, and in doing so the curvature of the basin of deposition would tend to straighten out. Whereas before the expansion there was a deep basin with a straight upper surface representing the last-deposited sediments, after the expansion the basin became less deep and the upper surface was a doubly inclined plane meeting in a crest in the middle where the thickest sediments had been deposited. This crest is the primary watershed of the country which originally stretched in an unbroken line from Cape Town to Delagoa Bay, but which is now broken once, and once only, by the Orange River at Aliwal North, the waters of this river having been forced over the watershed by the dam of lavas which were poured out in the Drakensberg. The Drakensberg volcanoes were consequently situated above sea-level and not submarine, as is often held to have been the case.

Besides this vertical uplift there was a lateral thrust also due to expansion. This, for some reason or other, found relief only on the south. On the north, perhaps because there was here the whole continent of Africa behind, no movement took place, but on the south there was only the Madagascar ridge, which we may suppose to have yielded somewhat to the pressure, and the movement once started caused the whole of the lateral thrust to become expended on this side. The shift of the Madagascar ridge can only have been small, not enough to accommodate the large amount of expansion caused by the intrusion of the Karroo dolerite. The surplus expansion was relieved by the beds between the dolerite and the old Madagascar ridge folding into a number of sharp synclines and anticlines. There

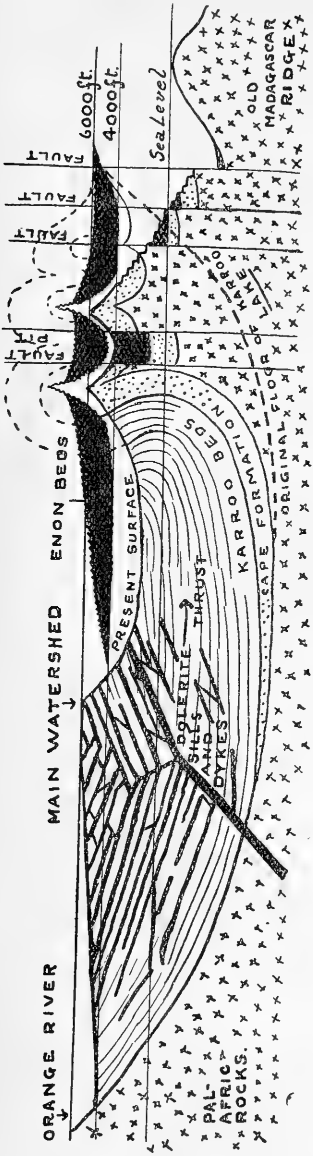


Fig. 1. Diagrammatic section through Cape Colony.

The Cape formation (Table Mountain Sandstone, Bokkeveld, and Witteberg Beds) is shown resting on Pal-afric beds (with crosses). They thin out towards the middle of the Karroo basin. The original basin of deposition is shown by the dotted line, and the old Madagascar ridge, now faulted below sea-level, formed the southern margin. The Karroo Beds are shown with the intrusive sills and dykes of dolerite. The Karroo Beds are scarped in the south, but fall gently in the north to the Orange River; the latter slope is very nearly the same as that which caused the main watershed to rise; the watershed is shown at the edge of the escarpment. The original folds of the Cape Mountains are indicated by dotted lines, and their contours in Lower Cretaceous times by wavy lines. The material (shown in black) resting on their flanks is the Uitenhage Beds (Lower Cretaceous), and very probably other and later beds. The manner in which these Cretaceous beds are let down into fault-pits into older and harder beds is shown between the two ranges of coast mountains as at Oudtshoorn, and by step faults as in the great Uitenhage basin. On the seaward side of the range the Klimakotopedim, on which the Alexandria Beds rest, is shown cut, sometimes in older, sometimes in Cretaceous rocks, down to the 90 fathom line (the Agulhas Bank). The descent to 400 fathoms is also shown, as well as the rise of the old Madagascar ridge on the far side.

is some difficulty in explaining how the earth's crust, structurally weak, can transmit a thrust of such magnitude; indeed, the area between the dolerite and the folded mountains is traversed by a large number of quartz-veins filling in fissures, showing that the country has been stretched. The explanation of this lies in the fact that the thrust was conveyed by an infinite number of pulsations, small earthquake waves, which, like the waves of the sea, battered upon the shore represented by the old Madagascar ridge and caused the pressure to accumulate by insensible gradation. At any rate the dolerite dykes and the folded mountains stand in the relation of cause and effect. The commencement of the movement was contemporary with the outbursts of volcanic energy in the Drakensberg and also in the north in the volcanoes of the Kimberley series of pipes. In the east the Karroo Lake had a deep hollow in which sedimentation went on after it had stopped in the west, and the last undoubted subaqueous sediments are Rhætic. The Cave Sandstone and Red Beds which immediately underlie the lavas are more of the nature of mud and ash poured out of the volcanoes; the vertebrates, however, found embedded in these latter are Jurassic—Dinosaurs and primitive mammals. The main folding was finished before the Cretaceous period, for the Neocomian beds are unaffected.

The folded mountains reached to a very great height as compared with the present sea-level, but then the land lay from 4,000 to 6,000 feet lower than it does now. The rocks involved in the folding and structurally weak from the bending yielded enormous debris heaps, *Schutt-halden*, which formed at their bases. There seems to have gone on a sort of contemporaneous erosion and deposit of a peculiar kind and on a gigantic scale, for the rivers and torrents with their burden of gravel cut a level peneplane at 4,000 feet above the present sea-level and then left behind on the plain a pile of gravel which reaches 2,000 feet in thickness in places. This is the Enon conglomerate, the lowest member of the Uitenhage (Neocomian) Series. The mountains, then much lowered in altitude by the action of torrents and swaddled at their bases with the Enon conglomerate, no longer formed the collecting-points for the moisture-laden clouds, and the country instead of being lashed with storms became tolerably dry, or even desert, with, however, occasional lakes. In Central Asia we have very similar conditions at the present day, and, to complete the similarity, the Himalayas, Karakoram, and Kuen-Lun Mountains shortly after their elevation yielded vast plains of boulders like the Enon at no very remote date, just as our coastal mountains in South Africa did in Lower Cretaceous times. The deposits of this dry stage are represented by the Wood Bed, the middle series of the Uitenhage formation; the strata consist of marls, gypsiferous clays, blown sand, and lake deposits. In the last a rich flora of Cycads, ferns, and conifers has been found which are of Wealden age. On the margins of the lakes Dinosaurs still continued to roam, but only a few have been found; one complete one unearthed at the Despatch Brickfields, near Uitenhage, was converted into bricks before it could be saved; only a few pieces have yielded Dr. Broom sufficient material on which to found his genus *Algoasaurus*.

The land, however, was sinking, and at the close of the Wood Bed period the sea invaded the land and flowed probably up to the central escarpment of the Karroo. The beds laid down are richly fossiliferous, and from them Plesiosaurs, Ammonites, Trigonias, and other Lower Cretaceous marine forms have been obtained. These are the Sunday River Marine Beds. Now comes a gap in our knowledge. From the Neocomian to the Mio-Pliocene nothing is known in the midlands of South Africa. In the east, in Pondoland, there is a patch of Upper Cretaceous deposits and in Zululand beds of a slightly lower horizon. In both these cases the strata lie against a fault-scarp of much older beds and have therefore been dropped down just as the Uitenhage Beds have been; in fact, there can be little doubt that the faults in both cases belong to the same system and are very little, if at all, separated in age. This consideration leads one to the conclusion that Lower Cretaceous beds occur beneath the Upper in Pondoland and Zululand, and that consequently the Lower Cretaceous strata in the midlands and west of Cape Colony were followed originally by Upper Cretaceous deposits, which have now, however, been entirely removed by denudation. In Madagascar on the west there is a complete conformable series through the Juras and Cretaceous to the Tertiary, and the tilting of these beds westwards connects the beds so tilted with the faulted strata in Cape Colony.

It should be noted that at this time Madagascar was in all probability joined to the mainland by a land bridge through the Comoro Islands, and in the bay between the island and the mainland the complete conformable series of rocks above-mentioned were laid down. Traces of the upper part of the series is found in Zululand, but the faulting to be described below intervened and cut up the mainland side of the bay. In Madagascar the eastern side is a sharp fault-scarp as shown by the almost straight coastline, but on the western side the beds have been merely tilted. We know from the fault-troughs in Baviaan's Kloof that as a rule the slices of the earth's crust let down in this region are faulted on the side towards the land and bent downwards on the side towards the sea, so on this evidence the deep channel between Madagascar and the mainland is a normal interrupted trough fault or pit of the Baviaan's Kloof type.

At any rate, we may suppose that after the Sunday River Marine Beds of Uitenhage were laid down, the whole of the southern portion of South Africa was beneath the sea, and beds of sand, mud, and limestone, now entirely removed, covered all the country even as far west as Cape Town, and that this deposition went on into the Eocene period.

At the close of the Eocene period, or at least before the Miocene, the old Madagascar ridge became faulted down. The crack or fault sliced off the eastern corner of South Africa and spread northwards along the Lebombo Mountains, separating the Eastern Transvaal from Portuguese East Africa, then upwards along the Shiré River to the great western and eastern rift valleys to the Red Sea. On the landward side of the fault the country rose in compensation. Denudation started to work at a rapid rate, removing all the loosely compacted rocks but recently laid down, and would have swept them entirely away but for the fact that there was developed a system of fault-troughs which let down slices of the earth's crust into pits where the loose Cretaceous rocks were protected by being entirely surrounded by hard ancient rocks. Although these fault-pits are shown in section as ordinary faults, they partake more of the nature of holes caused by tearing along a zone of shearing. One can illustrate their nature by taking a slab of stiff clay and pushing the two ends of it in different directions over a polished table; in the zone of shear a number of eye-shaped holes will appear, whose shape the fault-pits of the south-western districts of Cape Colony actually have, and it is in these eye-shaped holes that there now exists what little remains over of the Cretaceous beds.

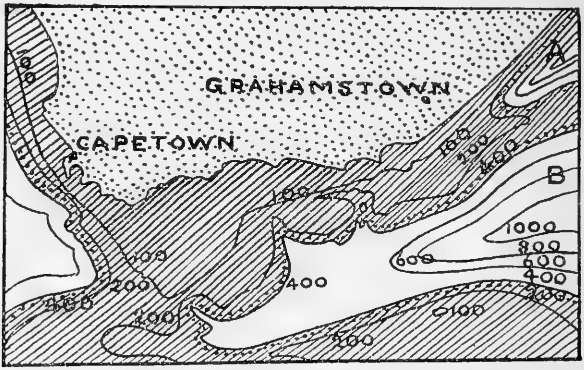


FIG. 2.

Sketch-map of the floor of the ocean south of South Africa, based on the Admiralty charts. The sculpturing of the sea-floor down to 400 fathoms is shown and also the tailing out of the deep trough (rift-valley?), A, that separates Africa from the Madagascar ridge, and the commencement of another, B, directed to the east. Dotted portion indicates present land surface; ruled portion the area of the sea-floor that shows evidence of terrestrial erosion.

If one glances at the sketch-map, Fig. 2, it will be seen why the faults which let down the Uitenhage Beds are connected with the Great Rift Valley System in Central Africa. The latter comes south through Lake Nyasa and along the Shiré River; then in a curved line there is a fault which forms the western boundary of a rift-valley, the eastern scarp of which is hidden under the sea, or, as I have previously mentioned, is probably represented by the monocline on the west of Madagascar. This great island is again simply a horst like the Colorado plateaux with fault on east and monocline on west. At all events, the fault-line from the Shiré River turns to the south-east and on the east there are low-lying tracts of land underlain by Upper Cretaceous rocks, forming Portuguese East Africa and Zululand; a last little patch is left near the Umzamba River in Eastern Pondoland. From here the fault-line forms the actual boundary of South Africa as far as the mouth of the Bushman's River, south of Grahamstown. The deep trough, A, in the sea-floor tails out here also, and the system of faults which lets down the Uitenhage

Beds begins. This system stretches certainly from the mouth of the Bushman's River to Worcester, a distance of 400 miles, in an east and west direction, although the direction of the faults in the various fault-pits varies owing to the original grain of the country which was determined when the mountains were folded; thus the Bushman's River fault along which the lower course of the river is cut is W.N.W.–E.S.E. The general arrangements of the series of fault-pits and their dominant marginal faults is east and west. The interruptions of the fault-troughs, which convert what are in all characteristics rift-valleys into a series of isolated pits, are always in a N.E.–S.W. direction, that is, in the direction of the faulted coastline of the eastern corner of South Africa and its accompanying trough in the sea close inshore. The E.–W. direction is that of the second and larger trough (Fig. 2, B) which also tails out here, but proceeds a little further west than the other, so it is to this fault-trough that the truncated end of South Africa owes its origin. The fault-pits in which the Uitenhage strata lie are due, therefore, to the crossing of two systems of faults, or rather are marginal shearing fractures of two great fault-troughs which are directed respectively E.–W. and N.E.–S.W. It is necessary, however, to establish that the E.–W. trough in the sea is a rift-valley. If we admit that the trough A is a fault-trough, which does not seem to admit of doubt, as we see one side of it actually above sea-level in Pondoland with Upper Cretaceous rocks against it, then the N.E.–S.W. fractures of the fault-pits with the Lower Cretaceous rocks against them are connected with it in the same way as the smaller trough-faults of Egypt are connected with the larger one of the Red Sea. The E.–W. fractures, which form the other two sides of the fault-pits, parallel to the E.–W. trough B, would also be connected with a fault-trough, and thus from their association with the other fractures make it highly probable that this second trough is a rift-valley beneath the sea.

I have said that Madagascar is a horst of the Colorado plateau type with strike a little east of north. If there are E.–W. rift-valleys, there ought to be horsts of the same nature as Madagascar with this strike. In Schott's map of the Indian Ocean accompanying Chun's *Aus den Tiefen des Welt-Meeres*, Jena, 1900, these E.–W. horsts are very clearly demarcated. From the south northwards, there is, first, two blocks extended east and west with straight sides, on which the Prince Edward and Crozet Islands lie, then the Rodriquez bank, and then the Seychelles bank. Corresponding to these there are straight-edged banks running N.–S.: first, that on which the Laccadive, Maldive, and Chagos Archipelago stand, then the banks of Saya de Malha and Albatros Island, north of Mauritius, and far to the south the bank on which Kerguelen and Heard Island stand; the last, however, trends west of north at about the same angle as Madagascar does east of north. All these submerged plateaux from their nature appear to claim to be parts of the fragmented Indo-African continent, and faults that left them standing while the rest of this part of the earth's crust sank were probably contemporaneous with those that affected the southern portions of Cape Colony. The only doubt that can be thrown upon this contemporaneity is due to the fact that the

Red Sea, which is a rift-valley belonging to the great Indo-African fragmentation, has sunk in Pleistocene times, at least the northern portion; in this case, however, the rift had already formed long previously, and the fact that the sea invaded the trough only in Pleistocene times merely indicates its depression below an arbitrary datum depending on the amount of sea-water upon the globe. The bottoms of other rift-valleys, such as those in Central Africa, are much above sea-level, as others, for instance that off the coast of South Africa, are much below. That movements should happen in Pleistocene times in these troughs is a natural consequence of the strained equilibrium resulting in large movements in the earth's crust, and may be regarded as 'posthumous' movements along lines of weakness formed long anteriorly, just as the fold of the Weald in the South of England is a posthumous fold which followed lines of folding that was brought to a close in Carboniferous times. What I wish to establish is that the general fragmentation of the Indo-African continent took place in pre-Miocene times and was finished in pre-Pleistocene.

The next event in South Africa of which we have any evidence is a peneplane now elevated 4,000 feet above sea-level. Only river gravels are found upon it, and these quite barren of organic remains. It is extensively developed on the inside of the coast ranges, and extends along the escarpment of the Karroo Beds in Fort Beaufort and King Williamstown; from Grahamstown it may be seen as a sharp line below the 6,000 feet level of the Great Winterburg and Amatolas. The 4,000 feet peneplane is thus a level of general denudation, and implies that the land stood at this level above the sea; it is quite different from the 4,000 feet level on which the Lower Cretaceous beds, the Enon conglomerate, was deposited, for this new 4,000 feet level cuts off the tops of the tilted Enon conglomerate and covers them with *remanié* gravels lying perfectly horizontally. We do not know the date of this plain because there are no organic remains in the gravels and sands with which it is covered, but the land was now again rising, and after cutting a very widespread peneplane at 2,500 feet above present sea-level, it rose to 15,000 feet above sea-level, when for the first time the Alexandria Beds, Mio-Pliocene, were deposited. The second 4,000 feet peneplane is thus about Oligocene or early Miocene.

From the 1,500 feet plain or coast shelf—for now the plains are no longer extensive peneplanes but narrow shelves fringing the coast—there are a succession of ledges cut at intervals of 50–100 feet downwards, extending like the steps of a flight of stairs to below sea-level. As our coast surveys show the sea-floor carved into narrow river gorges down to 400 fathoms, one may perhaps be justified in concluding that this level was at that time exposed as dry land. The submarine contours show that at 400 fathoms the old Madagascar ridge was connected to the Cape Peninsula, and that river courses ran both to the east and west from the narrow connecting ridge. From a general view of these contours one may infer that the river system at the time of maximum elevation was somewhat different from what it is now: only two rivers, the Gouritz and

Gamtoos, reached the sea; the others, which now have separate mouths, then formed tributaries of these two large rivers.

The movement seems a gigantic one, but the data we have to rely upon are sound; only the time taken for these changes of sea-level is open to some doubt. There has been rising of the land from the 4,000 feet peneplane to sea-level, and from here to the 400 fathom line, 6,400 feet, then a sinking of the land 2,400 feet to present sea-level. All this was accomplished in pre-Pleistocene times, because the rock-channels of the rivers which cut through this stepped plain, such as the Keurboom, Pisang, Zwartkops, Kowie, and Buffalo, are filled in now at sea-level with Pleistocene beds. Hence the whole oscillation took place within the Miocene and Pliocene times, 6,400 feet vertical rise and 2,400 feet vertical sinking, or 8,800 feet of total movement. If the evidence below sea-level is objected to, the undoubted movement is still 4,000 feet.

Certainly the portion from sea-level to the 90 fathom contour is cut into ledges such as one sees in Uitenhage or Pondoland; below this the descent to 500 fathoms is steep, and there is so much glauconite sand that the surface contours are obscured. Further out, the sea-floor rises again to 200 fathoms, and in one place opposite the Gamtoos River to 100 fathoms; this is the remnant of the old Madagascar ridge.

This stepped or terraced plain, covered with Alexandria Beds, which are the same when examined from either the top or intermediate levels or even from the lowermost at sea-level, belongs therefore to one and the same period. I have called such a stepped plain a klimakotopedim. Lyell describes a similar stepped plain in miniature in his *Travels in North America*, London, 1845, vol. ii, p. 39: "In proportion as the Ohio falls gradually in level after its inundations, it leaves a great succession of steps cut in its mud banks, each from 4 to 10 inches above the other. It appears to me an exact miniature representation of the form in which the waves have denuded the land on the sides of some valleys in the limestone districts of Sicily and other countries bordering the Mediterranean." The last fact is important, and one which I have not seen mentioned elsewhere, because this African stepped plain is covered with a deposit in which are found species identical with the Mediterranean Mio-Pliocene forms.

Since the land stood exposed down to the 400 fathom line it has sunk and the ends of the rivers of South Africa show deeply excavated rock channels now filled in with Pleistocene sand and clay. The present movement apparently is an elevatory one; recent sea-beaches are seen along the shore elevated 10 feet above sea-level, but no direct proof is forthcoming.

The movements I have been discussing are direct elevatory ones, or the reverse, of the solid crust and were caused by folding and faulting. The alteration of sea-level due to the attraction of the outstanding portion of the land on the water must also have been intense; when the folded coast mountains were first formed a great pull would have been exerted on the sea by these towering ranges, and, as they became denuded and surrounded with debris and eventually swamped by the sea, their attraction became reduced to nothing. Now in the course of ages they have once again emerged by the removal of the loose material around them, and they rise to the 6,000 feet level and must by their attraction cause the sea to heap up in their neighbourhood. As a matter of fact, it is probable that the sea-level is higher around Cape Town with its backing of great mountain ranges than it is at East London, where there is merely a stepped plain presented to the sea.

III.—Palæontology and Bernard's Biological Theories.

By W. D. Lang, M.A., F.Z.S.

I.

PALÆONTOLOGY is the biology of fossils. The palæontologist, therefore, is bound to consider modern biological views in order that he may test them in the light of his science. It is intended here to apply to one class of fossils the fundamental principles upheld in a remarkable work by the late H. M. Bernard, entitled *Some Neglected Factors in Evolution*,[1] really two books under one cover, the first dealing with the ultimate structure of protoplasm and the second with a method of organic evolution. The principles underlying the first suggest the methods of the second; so that in approaching the second a thorough knowledge of the first is needful. Before applying it let us examine the theory itself.

Hitherto, says Bernard, the morphological aspect of biology has been dominated by the idea that all organisms are either cells or cell-aggregates. The cell has been regarded as the unit of all higher structures, and, although in its turn the cell is variously composed of simpler factors (cytoplasm, nucleus, chromosomes, etc.), these have never been, in fact obviously cannot be, regarded as homogeneous units, building up the cell in the same manner as the cell builds up a tissue and, finally, a whole organism. Now this cell-doctrine is far too rigid to explain many well-known morphological phenomena, and to do so in terms of the doctrine involves extending the definition of a cell beyond convenience; and the idea of a cell has consequently obscured the significance of what has been observed. Some authorities, it is true, have refused to wear the blinkers of the cell-doctrine, and, though they have seen further in consequence of their action, they have not co-ordinated their observations by any theory transcending that based on the cell.

Bernard's theory demands that the cell shall be itself an aggregate composed of homogeneous units. In order to discover these units it is necessary to determine what morphological factors invariably are present in protoplasm. These are found to be three: a deeply staining factor bearing chromatin and occurring in minute bodies—chromidia, fibrous filaments composed of linin, and a pervading liquid matrix. The simplest imaginable connected and symmetrical grouping of these factors has the form of a three-dimensioned linin network with the chromidia at the nodes and the whole bathed in

[1] *Some Neglected Factors in Evolution, an Essay in Constructive Biology*, by Henry M. Bernard, M.A. Cantab., F.Z.S., ed. by Matilda Bernard. 8vo; pp. xxii + 490, text-illustrations. G. P. Putnam's Sons, New York and London, 1911.

the 'cytoplasmic' matrix. The unit of this arrangement, then, is a single chromidium with radiating linin strands; and a homogeneous aggregate of such units is the linin-chromatin, or, as Bernard calls it, the 'protomitomic', network.

Such a network is the condition of cells that have no apparent nucleus, or of those which, in terms of the cell-theory, the nucleus is fragmented. And the reason why this structure has not hitherto been postulated as fundamental in all protoplasmic bodies, is that in general circumstances the linin is invisible by our present means of vision; but when chromidia stream along the filaments, owing to their staining properties, they cause the filaments to appear. Then they have been observed, for instance, in a nucleus dividing by mitosis; and variously accounted for. For the linin strands are the paths of the chromidia which in their turn are the storehouses of energy. Where work is done, and in proportion as more or less energy is required, thither and in greater or less quantity stream the chromidia along the linin strands. The strands are essentially contractile as well as capable of transmitting stimuli from the exterior to other portions of the network, and it is specialized bundles of linin strands that ultimately form nervous and muscular tissue. It is along them, too, that waste matters travel outwards and are deposited either around the strands (or bundles of them) or at their tips, forming an endo- or exoskeleton.

The cell is derived from the primitive linin-chromatin network by the massing together of the nodes and the consequent tangling of the linin threads. The massed nodes constitute the nucleus, and the linin filaments, though tangled, have as a whole a radial arrangement, and their ends, projecting from the 'cytoplasmic' matrix, either singly or in strands, appear as cilia.[1]

Homogeneous aggregates of cells form three-dimensioned networks very similar to the primitive protomitomic network, but on a larger scale and essentially of a more complex structure. Examples of such are *Volvox* (fig. 21, p. 107), the larval sponge (fig. 14, p. 91), and the tissue of the vertebrate retina (fig. 33, p. 218).

Such, in bald outline, is Bernard's protomitomic theory, if I have rightly understood it. The evidence adduced in its support is mainly that of structures such as the vertebrate retina and the nuclear spindle and centrosomes of karyokinesis, difficult of explanation by the cell-theory, but easily accounted for if Bernard's point of view is accepted. Moreover, his view reconciles different and apparently exclusive theories of protoplasmic structure, such as the 'foam-structure' theory of Bütschli, founded on the globular appearance of the albuminous matrix between the protomitomic meshes, and the 'biophor' theory of Altmann, the granules of which are the chromidial nodes.[2] The protomitomic theory does not annihilate the cell-theory,

[1] Bernard's explanation of the nuclear wall as a felted tangle of linin threads is not very convincing, for the tangling would, presumably, be greatest at the nucleus and *gradually* less towards the periphery of the cell.

[2] The reader must refer to the work itself to gain a proper idea of the number of otherwise inexplicable phenomena in morphology that can be readily construed in terms of the protomitomic theory.

rather it transcends it by regarding the cell as one particular kind of grouping of homogeneous units themselves built on a definite pattern. Thus, while the cell-doctrine lays stress upon the nucleus and the cytoplasm as essential factors of the cell, Bernard emphasizes the nucleus and the linin threads, the cytoplasm being composed of these and a pervading albuminous matrix. The significance of each point of view is seen when cell-aggregates are considered. To the cell-doctrine they are merely aggregates, though, since they act as a whole, there is some unknown co-ordinating influence. This, according to Bernard, is exerted by means of the physical continuity of the linin threads from cell to cell, continuous because they have never been separate. For a dividing nucleus implies a division of every chromidial unit of which it is composed and a longitudinal splitting of those linin threads in the plane of division and a lengthening of those at right angles to this plane.

The invariable presence of linin threads and their continuity from cell to cell is thus the essence of the theory from the point of view of the cell-doctrine. And here the critic may find an assailable point. Bernard's position is that, except when chromidia are travelling along them, the linin threads are invisible (with our present powers of vision). The scientific purist may deny the right of assuming the presence of a structure in any case when its existence cannot be proved by definite tests; the onus of proving the linin threads' existence in every case lies with Bernard. Bernard adduces certain cases where the threads are visible, shows that the protoplasm is then in a condition (e.g. when repeated nuclear division is taking place and chromidia streaming along the threads in consequence, or when waste products are being copiously conveyed along them) when on *a priori* grounds it is to be expected that the threads will temporarily be visible, and argues that it is fair to assume that they are always present, though often invisible. He thus leaves it for his critics to prove the absence of threads, disarming criticism by presenting a negative for proof. Future work alone will show whether the threads are invariably present. Hitherto they have not been sought, and have been noticed only when they could not well be disregarded. It is incumbent upon future workers to have this theory in mind and in its light to test the work already done. It is for this testing that Bernard pleads.

Bernard's first book, then, might be summarized as follows:—Protoplasm, in the simplest manifestation of its structure to which our present powers of vision can take us, consists of a network of linin threads with chromidia at the nodes, bathed in an albuminous matrix; a particular form of such a network, wherein the chromidia are massed in a central ball and the linin threads consequently tangled but still radiating from the central mass of chromidia through the albuminous matrix to the surface, constitutes the typical cell of the cell-theory.

II.

The idea of a cell as a particular grouping of homogeneous units, and at the same time one of many similar units that build up an organism, led Bernard to conceive the possibility of a unit of higher degree than a cell, from which higher metazoa were built; and he thinks he has found this in the 'gastræa'—the simplest expression of the morphic principle of the Cœlenterate; and above the gastræa two more units of progressively higher order. In each case more complex organisms are formed by aggregations of similar units, and one specially efficient form of grouping constitutes a new unit from which the process may begin again.

Hitherto organic evolution has been looked upon as an advance from the simple to the complex, from the homogeneous to the heterogeneous, and the advance along any one line as straightforward, though the steps may be more or less gradual or sudden. But, in the light of different orders of units, organic evolution is seen to proceed in periods, and periodic or rhythmic evolution is the theme of the second part of Bernard's book.

How many pre-cellular periods have occurred we do not know, but we know one—that of the protomitomic network seen in certain organisms (e.g. microbes and other non-nucleated protoplasmic bodies), and we may reasonably expect that earlier periods behaved similarly to this and to all subsequent periods. Now one fundamental character common to the units of all periods is an alternation of growth and fission; the unit cannot surpass a certain maximum size, and when this is reached it divides by fission (secondarily modified into budding). The simplest conceivable unit is a molecule of protoplasm. If such existed as a period, we must allow that it differed from every inorganic molecule by the possession of this periodic rhythm of growth and fission as well as the two next-mentioned characters. The first of these is the capacity of forming colonies by means of incomplete fission. The colonies are formed in great variety of manner, and one particularly efficient arrangement forms a new unit. A third fundamental property of the units is that of morphic response to the environment. That is, by exploring new environments, their structure (often only after the lapse of generations) becomes variously and suitably modified. Now the process of organic evolution seems to have been as follows:—A structural unit (of whatever order) multiplying by fission spreads in all directions into new environments and becomes accordingly variously modified, i.e. it passes from the simple to the complex, from the homogeneous to the heterogeneous. Simultaneously, by incomplete fission it forms colonies—homogeneous aggregates, whose units, however, are variously arranged; and one especially efficient arrangement becomes a new unit. The process is then repeated as a second period, and so on.

We have spoken of a hypothetical molecular period. Other periods are passed through until a pre-cellular period of which we have knowledge is attained. This has the form of a chromidium with radiating linin filaments. A colony of such units is the protomitomic network. One particularly effective arrangement of this is the cell, formed by a massing of all the chromidial nodes into a central nucleus. The cell is the new unit of a new (cellular) period. As a unit it has advanced from the homogeneous simple form to the heterogeneous complex structures such as *Paramœcium* and the

Radiolaria. As colonies formed of homogeneous units it has built up certain forms such as the Sponge, the Cœlenterate, and some Flat-worms.[1] Now the efficient arrangement of the pre-cellular unit that gave rise to the cell was obtained by the massing of chromidia (the essential chemical factor of the organism) to the centre, and by spreading around this central mass radiating fibrous elements. The same principle is seen in the gastræa, but here the massed nuclei surround a central digestive cavity, while in the outer zone the fibrous elements are specially developed and already are beginning to differentiate into muscles and nerves. The variety of cœlenterate forms shows the passage in this period from the homogeneous to the heterogeneous, while colonies of Corals, Hydrozoa, etc., are homogeneous aggregates. Bernard supposes that the next new unit was formed by a colony arranged so as to form a chain of gastrææ with the Cœlentera of all the individuals connected up and the muscular and nervous systems better developed. Such a colony would be primitive annelid, and those annelids that branch and form chains of individuals represent aggregates of the new unit.[2] If the passage from the gastræal to the annelid period is scantily and unconvincingly demonstrated, still more so is that from the annelid to the vertebrate period. Bernard dismisses this with very few words; and here is, perhaps, the weakest part of his book. A scheme of animal evolution to be convincing should above all help to elucidate the vexed question of the origin of the vertebrates, instead of slighting it. After the vertebrate unit is reached, the aggregates are social, and, since the tie connecting the individuals is no longer a physical one, the scheme passes out of the natural sciences into the metaphysical, and consequently no longer concerns us as palæontologists.

III.

It is not the object of this paper to give all the evidence for and against the views put forward, and the reader must refer to the work itself to form a true judgment. Had Bernard lived longer, no doubt he would have tested his theories fully; as it is, he appeals to his readers to do so, and, if this sketch has been the means of bringing his views to the notice of palæontologists, it will have accomplished an object. But the paper is primarily intended to show how Bernard's theories may be applied directly in palæontology and give a helpful view of phenomena.

Two outstanding points in Bernard's book are his insistence on the

[1] In embracing Mollusca among simple cell aggregates and apart from annelids, surely Bernard fails to account for such forms as show traces of segmentation and other suggestions of alliance with annelid worms, such as the trochosphere larva; see Pelseneer, "La Classification générale des Mollusques": Bulletin Scientifique de la France et de la Belgique, vol. xxiv (1892), pp. 368–71, 1893, and "Recherches morphologiques et phylogénétiques sur les Mollusques archaïques": Mémoires Couronnés l'Acad. roy. belgique, vol. lvii, pp. 83–8, 1899.

[2] The position assigned by Bernard to *Sagitta* is interesting. It is an aggregate of gastræal units arranged on a different plan from the typical annelid grouping and near that of the hypothetical vertebrate ancestor, but, being of insufficient efficiency, it has failed in its turn to become a new unit.

universal presence and importance of radiating linin threads that connect unit with unit and the periodicity of evolutionary processes. In consideration of the first point, Bernard claims as one of the most primitive and fundamental functions of the linin filaments the conveyance of waste matter towards the periphery of the organism. In some cases waste matter is deposited around the filaments as a sheath, and so spicular skeletons are formed. In other cases the waste matter is laid down at the ends of the filaments forming cuticular and other exoskeletons. Under the former category fall the Alcyonarian and under the latter the Madreporarian coral skeletons. Now two differing theories have been held regarding the formation of the latter skeletons, namely (1) that ectoderm cells secrete calcareous matter on their outer surface,[1] and (2) that ectoderm cells secrete such matter internally and gradually convert themselves into the granular elements of the skeleton.[2] The last great work on the microscopic structure of the Madreporarian skeleton was that of Ogilvie,[3] who described the granular unit that composed the coral skeleton as a cake-shaped mass built up of calcium-carbonate fibres and produced by a calcified ectoderm cell ('calicoblast').[4] Ogilvie claims to have found organic matter (the remnant of the chalicoblast) mixed up with the granule, so that the granule is not a mere secretion on the outside of the ectoderm cell (as Bourne has since reaffirmed).[5] Whichever view is right, neither explains the minutely fibrous structure of the granule. The simultaneous secretion of all the chalicoblasts forms a pavement of granules, and beneath this another layer, and so on, until the skeleton consists of many growth-lamellæ. Regarded in a direction at right angles to the plane of the secreting surface, the skeleton consists of piles of granules heaped up over the chalicoblasts, though, naturally, not so regularly as can be imagined.

Now, instead of a row of chalicoblasts laying down calcium carbonate within or without themselves, let us, with Bernard, regard the secreting surface as a cytoplasmic plane studded with the ends of the bundles of linin filaments, each conveying calcium carbonate from the interior and laying it down at their ends. The resulting skeleton would be a succession of sheets, each a superficial layer of minute specks of calcium carbonate far smaller than the granule secreted by a chalicoblast. Regarded in a direction at right angles to the secreting surface, the skeleton would be seen to consist of fibres, each composed

[1] Von Koch, "Ueber die Entwicklung des Kalkskeletes von *Asteroides calycularis*, und dessen morphologischer Bedeutung": Mittheilungen aus der zoologischen Station zu Neapel, vol. iii, pp. 284–92, 1882; and Bourne, "Studies on the Structure and Formation of the Calcareous Skeleton of the Anthozoa": Quart. Journ. Micro. Sci., N.S., vol. xli, pp. 499–547, 1899.

[2] Von Heider, "Die Gattung *Cladocera*, Ehrenberg": Sitzungsberichter der Kaiserlichen Akademie der Wissenschaften, Wien, vol. lxxxiv, pt. i, pp. 634–68, 1882; and Ogilvie, "Microscopic and Systematic Study of Madreporarian Types of Corals": Phil. Trans. Roy. Soc. Lond., ser. B, vol. clxxxvii, pp. 83–345, 1897.

[3] Op. cit., under (2).

[4] 'Chalicoblast,' von Heider, op. cit., under (2), p. 651, not 'calicoblast', after Bourne and Ogilvie (χάλιξ, 'a stone').

[5] Bourne, "Anthozoa," p. 80, in Lankester, *A Treatise on Zoology*, 1900, pt. ii.

of a pile of the minute specks of calcium carbonate and reposing on the end of a bundle of linin threads. We have thus reached a smaller skeletal unit than the granule, namely a micro-granule, secreted at the end of a linin-thread-bundle. A pile of these forms a skeletal fibre; a bundle of fibres forms a granule which exists as a separate entity in virtue of the chalicoblasts being differentiated as cells, i.e. though connected by linin filaments the cytoplasm is arranged in groups each dominated by its several nucleus. Except, however, at the surface where the skeleton has only just been secreted, the outlines of the granules vanish, and the skeleton has a fibrous structure alone.

Any section of a fossil coral, if well enough preserved, shows a fibrous structure (I am not aware that fossils are ever so well preserved that the lines of growth described by Ogilvie in recent corals appear), and the septa invariably, and other elements variously, have a median (generally) dark line. This dark line is the expression of the secreting surface folded upon itself; each side of the fold secretes the fibrous skeleton, and the line marks the junction of the two layers. The skeletal parts other than the septa may be interpreted as secreted by a double or single ectodermal surface according to whether they have or have not the median line. Ogilvie explains how complex folding of the secreting surface causes the skeletal fibres to appear rather to radiate from centres than to be pinnately arranged on each side of the median line.

We have now seen that Bernard's theory explains the fibrous coral skeleton whether the fibres appear in the section of a fossil or as composing a granule isolated (as achieved by Ogilvie) from the septal surface of a recent coral. It is also conceivable that, if secretion were quickly taking place, calcium carbonate might be deposited just beneath the surface of the cytoplasm round the end of a linin-thread-bundle as well as at its end, and so pieces of cytoplasm might thus get entangled in the general skeletal layer and give the appearance that suggested to Heider and Ogilvie that a whole chalicoblast was converted into a granule of calcium carbonate.

Periodicity in evolution is the second principle just mentioned as standing out from Bernard's work. It is here suggested that this principle has a far wider application than that given it by Bernard. Demonstrated by him as evident in the evolution of animal phyla, periodicity is here claimed as bound up also with ontogeny and possibly related to tachygenesis.[1]

Wilson has shown in the development of the coral *Manicina*[2] that the first six mesenteries appear singly, though the last four of these follow so closely upon one another as rather to resemble the entrance of a pair of pairs. In other Cœlenterates the mesenteries have been described as appearing in pairs or in cycles. The first mesenteric period of *Manicina*, then, may be called the 'single' period, since its structural unit is a single mesentery; its first phase (anabasis) is the production of the first two mesenteries, one after the other; its

[1] Hyatt, "Bioplastology and the related branches of Biologic Research": Proc. Boston Soc. Nat. Hist., vol. xxvi, p. 77, 1893.

[2] Wilson, "On the Development of *Manicina areolata*": Journ. Morph., vol. ii, pp. 191–248, 1889.

developmental aim is to produce mesenteries in pairs, shown in the second phase (acme), and so perfected in the third phase (katabasis) that this phase reproduces the idea of the first, since the two mesenteries appear practically as a single unit. Our new structural unit is now a pair of mesenteries, and the second six mesenteries appear in pairs and constitute a second period. We are, however, not directly concerned with the further development of mesenteries, for it is in fossils that we are looking for periodicity in development. But, since the septa follow and to some extent are determined by the mesenteries in number, position, and time of appearance, it is well to realize that mesenteries have a period in development whose structural unit is a single mesentery, prior to one with a pair of mesenteries for its structural unit. The most primitive septal development yet described is that of *Zaphrentis*.[1] Carruthers figured three stages in a 'paired' period in this form, namely, stages with two, four, and six septa respectively. The next period in *Zaphrentis* and in Rugose corals generally has still a pair of septa for its structural unit, but instead of being added to the previous septa as if these constituted but one system, the new septa appear in pairs independently at two levels, one in the 'dorsal' and the other in the 'ventral' parts of the corallum, as if the previous septa formed two systems. Since the resulting appearance is three fossulæ, this period may be called the 'fossular' period. After a time, new septa no longer are added in pairs about the two levels, but a 'cyclic' period is introduced, the structural unit being a complete cycle of septa interposed between those already existing. Three points are remarkable in the cyclic period; in, at any rate, most Rugose corals but one cycle is thus produced; often the cycle is not perfect in its time of appearance, but the septa in the neighbourhood of the counter-septum progressively anticipate those in the other half, showing how the cyclic method originated; there is often, too, an acceleration of the cyclic period upon the fossular period, since the first cyclic septa may appear before the last fossular.[2]

Recent corals start with six or twelve septa appearing simultaneously, doubtless owing to the fact that, on becoming fixed, the larva already has twelve or more mesenteries.[3] It would be impracticable for the complete appearance of the septa, like the mesenteries, to be pushed back by tachygenesis into the larval period, for the little coral, embarrassed with a cycle of septa, would be too straight laced to swim in comfort. The septa are therefore suppressed until they may conveniently appear, and then they arrive in numbers appropriate to the stage of development attained by the soft parts. The septa, then,

[1] Carruthers, "The Primary Septal Plan of the Rugosa": Ann. Mag. Nat. Hist., ser. VII, vol. xviii, pp. 356–63, 1906.

[2] For example of these points see Duerden, "The Morphology of the Madreporaria.—VI. The Fossula in Rugose Corals": Biol. Bull., vol. ix, pp. 34–7, figs. 7–10, 1905.

[3] e.g. in *Astroides*. Lacaze-Duthiers states: "C'est lorsque le nombre 12 des divisions du polype est atteint . . . que se produisent les dépôts calcaires à peu près en même temps et de même dans toute la zone" ("Développement des Coraillaires, Deuxième Mémoire": Archives de Zoologie expérimentale et générale, vol. ii, p. 328, 1873).

of recent corals already appear in cycles, and other complications mark their periods.

It is easy to see how, by tachygenesis, a period of, for instance, six separately appearing mesenteries (or septa) may be condensed into one of three stages where the septa appear in pairs; and this, in turn, to a single cycle. But tachygenesis generally is shown by the greater condensation of the earlier stages. In the case considered, however, it is the earlier periods that are the least condensed and the later progressively more so. Again, one period may tend to overlap a previous period, as, for instance, the cyclic anticipating the end of the fossular period in Rugosa. This is quite in keeping with the trend of tachygenesis.

Bernard's evolutionary units are themselves the totals formed of units of a former period. So it is in ontogeny. The post-embryonic life-history of a coral involves a radially symmetrical free-swimming stage (very much reduced in recent corals[1]), a stage of bilateral symmetry, shown by the elongate shape of the mouth and by the position and arrangement of the muscle bands of the mesenteries, and a secondarily radial ('biradial') stage in which a radial symmetry tends to be resumed. Similarly, *Zaphrentis* (to take the example of septal development we have already cited) presumably during the free period of its life passed through a stage with no septa, then, on becoming fixed, one in which two, four, and finally six septa are bilaterally arranged, to a stage which has become again radially symmetrical by the equalization in length and spacing of the septa. The fossular period is the anabasis of a second wave of symmetry, bringing the radial up to the acme of bilateral symmetry, and the cyclic period its katabasis down to a secondarily radial symmetry. That is, the first-described periods of septal arrangement themselves become stages in periods of alternating bilateral and radial symmetry.[2] A similar rhythmic process of periods has been demonstrated in the costal development of *Parasmilia*.[3] Thus Bernard's periodic rhythm of units in animal evolution as a whole finds corroboration in the facts of coral development, and, as a point of view, is useful for estimating the relations of various phenomena in phylogenetics.

IV.—Note on the Pollurian–Trewavas Coast Section, Cornwall.

By Upfield Green and C. Davies Sherborn.[4]

ASSUMING that the Lizard Peninsula is a pre-Cambrian complex (Flett), and that the Hornblende Schists of Pollurian have nothing to do with the northern sediments, it will be well to call

[1] Lacaze-Duthiers, op. cit., pl. xiii, fig. 9.

[2] These alternating periods were fully appreciated by Duerden, "The Morphology of the Madreporaria.—V. Septal Sequence": Biol. Bull., vol. vii, pp. 99–101, 1904.

[3] Lang, "Growth-stages in the British species of the Coral genus *Parasmilia*": Proc. Zool. Soc. Lond., 1909, pp. 287–90.

[4] This paper was written in May, 1910. In the previous month the Director of the Geological Survey kindly allowed us to look at the unpublished map, for which favour we undertook to give priority to the Survey. The Survey Memoir having now appeared, we print our views as then written.

attention at first to the extensive folding of the rocks at Pollurian, which gradually loses itself as we pass northward in a series of lengthening S.E.–N.W. folds, finally dying away at Porthleven into more or less horizontal beds as we approach Trewavas. Minor contortion is ignored.

On the north side of Pollurian Cove we see black slates with inclusions of grit and limestone lenticles, the Veryan Beds of the Survey.[1] The limestone lenticles seem rare at Pollurian itself, but occur abundantly in Gunwalloe Cove and in Jangye Ryn, north of Gunwalloe Cove. No fossils have yet been found in these lenticles at this spot, but we found one lenticle in Gunwalloe Cove itself so crushed as to show a cone-in-cone structure[2] which would totally destroy any vestige of organisms, and in this particular these lenticles differ from those found at Porthluney and Porthalla, which contain Silurian fossils. These Veryan Beds form the bulk of the cliff on which stands the Wireless Telegraph Station of Pol Dhu, the base of the Towan Cliffs, the base of Castle Hill, on which Gunwalloe Church is built, and rise again on the south side of Jangye Ryn, the crest of their arch appearing on the shore, while the denudation of the softer overlying and crushed arch of Porthscatho Beds has caused a little S.E.–N.W. cove, as seen on the Ordnance Survey map. The crush at this point appears to have been excessive, for we seem to find pieces of Porthscatho Beds in the top layer of the underlying Veryan. In Jangye Ryn itself the Veryan Beds are seen here and there along the shore with lenticles of bluish-grey limestone full of quartz veins, but the beds gradually die out and are probably last seen in Helzephron Cove.

The Porthscatho Beds first appear in the road leading down to Pol Dhu Cove from the hotel; they form the upper part of the Towan Cliff, Castle Hill, nearly the whole of Jangye Ryn, and the coast to Tremearne Cliffs. They are highly contorted, thrown into sharp folds at Jangye Ryn, and, as we pass north, gradually into longer and longer S.E.–N.W. folds, until at Porthleven they become fairly horizontal and form bold cliffs of grit, breaking up into cubes and tables (much like the South Lizard Hornblende Schists) as one nears Trewavas.

At Gunwalloe Fishing Cove we see a small infold of the Falmouth Slates, and other infolded patches of these slates are met with in the coast section at the base of the cliffs between Gunwalloe Fishing Cove and a point a quarter of a mile south of Looe Bar, while traces can still be found north of Looe Bar infolded among the Upper

[1] The "Mylor-Veryan" of Green (95 Ann. Rep. Roy. Cornwall Geol. Soc., 1908, p. 7). We now recognize the "Mylor" Beds of the Survey to be the upper part of the Porthscatho Series, which, if needing a special name, can be called "Mylor".

[2] Portions of this specimen are now preserved in the Brit. Mus. (Nat. Hist.) and in Jermyn Street Museum. In Pollurian Cove we found a thin band in the Veryan containing discs of limonite after iron pyrites about 12 mm. in diameter; these are comparable to the 'coal-money' found in the North of England (L. J. Spencer). Specimens of this rock also have been given to the above-mentioned museums.

Porthscatho Beds in the first 50 yards of the shore section. Traces of the Falmouth Beds can be found here and there on the fields to the west of the Helston–Lizard road, but the bulk of the debris is of Porthscatho age, and we consider that nearly the whole of the Falmouth Beds have disappeared except for the small patches described as existing on the coast, and the similar patches preserved by infolding among the Porthscatho on the land surface.

The peculiar characteristic rock of the Lower Porthscatho—the massive detrital rock like the well-known Grampound Grit—is seen but once north of Looe Bar (just past the Looe outfall), but this bed may be an ash-bed in the Upper Porthscatho of similar nature to the characteristic rock.

We consider all the 'Mylor' Beds of the Survey as the upper part of the Porthscatho, which in our opinion continues right up to the granite at Trewithick.

There is a very interesting little infold of slate with inclusions at the Looe Bar outfall, associated with the 'ash-bed' mentioned above. This is similar in appearance to some of the Veryan, but the great mass of the Lower Porthscatho which comes over the Veryan does not occur at this point, and one must regard the bed as of merely local stratigraphical interest belonging to the Upper Porthscatho Series.

The Upper Porthscatho consists of thick gritty slates, which weather yellow, bands of gritty slates weathering ashy-grey, and black micaceous sandy slates locally called 'blue-stone'. Quarries are not abundant, and the first sign of 'spotting' in the slates we met with was north of Tremearne Cliff at the 212 feet level on the main road about a third of a mile from the granite of Trewithick.

Having examined this fine coast-section we see no reason to alter the opinion expressed by one of us (Green, Geol. Mag., 1904, p. 401; 95th Ann. Rep. Roy. Cornwall Geol. Soc., 1908, p. 7) that the whole of these beds—Dartmouth, Falmouth, Ladock, Grampound, Manaccan, Mylor, Porthscatho, and Veryan—whatever they may be designated, are of Gedinnian age and have nothing to do with Silurian, Ordovician, or Cambrian rocks, and we consider the stratification of the older Cornish rocks from above downwards to be as follows:—

Gedinnian = Lower Devonian	Falmouth (includes beds called Dartmouth). Porthscatho (includes beds called Mylor, Grampound, Ladock, and Manaccan). Veryan (beds containing lenticular inclusions yielding Ludlow, Wenlock, and Woolhope fossils).
Ordovician.	Quartzites[1] (of Ordovician age with characteristic fossils).

[1] That the Ordovician Quartzites of the Gorran–Veryan–Manaccan anticline once existed in this area is evident from the abundance of the rock in the walls at White Cross and elsewhere. As it is continually being broken up for road-metal, the dotted lines on the old one inch map (Sheet 13, 1839 and 1866) of De la Beche will soon be the main record of its existence in the area.

NOTICES OF MEMOIRS.

I.—The Volcanic Rocks around the Ord Hill of Rhynie, Aberdeenshire.[1] By William Mackie, M.A., M.D.

These rocks occupy an area of two-thirds of a mile in length by a quarter of a mile in breadth, of which Ord Hill marks the centre, about half a mile west of the village of Muir of Rhynie, West Aberdeenshire. The group embraces at least three independent lava flows, with associated tuffs and interbedded and overlying sedimentary rocks, and lies on an eroded, eastward-sloping surface of the diorites and gabbros of West Aberdeenshire—rocks which have been considered to represent an early and basic modification of the younger Grampian granite—and are cut off on the east by the boundary fault of the Old Red Sandstone outlier of Rhynie and Kildrummy. A small outlier limited to two or three square yards of surface, and representing a single lava-flow, lies on the edge of the serpentine mass of Cnoc Cailliche about a mile south from the extreme southern end of the main area. The volcanic members of the group consist of grey to greenish coloured rhyolites, showing in places fine vesiculation and beautiful fluidal banding. The usual minerals of such rocks—quartz, orthoclase, muscovite, biotite with at times an occasional augite, are present in an amorphous base. Flow-brecciation is a frequent feature, and evidence of the effect of pressure is not entirely absent. The tuffs consist of fragments of rhyolite rocks—occasionally up to 2 inches in diameter—often rounded and encircled with glassy coronas exhibiting fluidal banding. Broken crystals of quartz and orthoclase, as well as considerable fragments of older tuffs, are also present. The sedimentary rocks of the group consist of very hard siliceous grits which, on microscopic examination, often show the presence of fragments of volcanic rocks of the same general characters as the associated lavas. These fragments are generally larger in size than the accompanying fragments and grains of sedimentary origin. The whole of the group is characterized by the presence of numerous, often very fine, secondary quartz infiltrated veins, and at one part in the sedimentary division these veins make up quite half the bulk of the rock.

Two small masses of biotite granite containing much microcline break through the diorite immediately to the west of the area. With these the volcanic members of the group may or may not have a genetic relationship.

As regards the age of these rocks, it is impossible to arrive at a very definite conclusion. They are manifestly younger than the diorite, but are probably considerably older than the oldest beds of the Old Red Sandstone of the adjoining area. The lavas being throughout of acid type, it is evident that they cannot be correlated with the interbedded andesites of the local rocks of Old Red Sandstone age.

II.—The Millstone Grit of Yorkshire: Some New Evidence as to its Source of Origin.[1] By Albert Gilligan, B.Sc.

More than fifty years ago Dr. H. C. Sorby attempted to trace the source whence the material which makes up the Millstone Grit had been derived, by making a collection of pebbles which occur so abundantly in some of the beds. Among these he found some small fragments of mica-schist, quartz-schist, and a few pebbles of undoubted granite. The largest pebble he obtained was about 4 inches in circumference, and of a type resembling a fine-grained syenite of greenstone,

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

but too much decomposed to be accurately identified. The pieces of granite were composed of quartz and felspar, suggesting by their appearance derivation from coarse-grained granites. Pebbles of quartz he found to be commonest, and he also described some pieces of white or brownish orthoclase felspar.

The granites he found were quite unlike any with which he was acquainted in the British Isles, being too coarse and much more like those of Scandinavia. Further, the current-bedding, which Dr. Sorby examined over an area of twenty-five square miles, pointed to a drifting from the north-east, and he therefore suggested some south-westward prolongation of an ancient Scandinavia as the source of origin of the material making up the great mass of the Millstone Grit of Yorkshire. Since this early work by Dr. Sorby nothing has been added to our knowledge of the lithology of this, to most people, uninteresting series of rocks. The late Mr. A. Longbottom, B.A., of the Nigerian Survey, collected some very large pebbles from the Middle Grits of Silsden. These have been examined by the author, who has also extended his researches into the other beds of the series in various parts of Yorkshire. Some of the pebbles are of a very large size, one obtained from Netherwood Plantation Quarry, Silsden, measures 10 inches by 8 inches by 3 inches, and is a reddish granitoid rock with large porphyritic felspar. The pebbles show a remarkable assemblage of rocks, igneous, sedimentary, and metamorphic all being represented, but by far the commonest are acid igneous rocks—granites, quartz, and felspar porphyries. Only one specimen of basic igneous rock has been found. The metamorphic rocks are quartz-schist and mica-schist, with a few fragments of gneiss. One of the mica-schist pebbles has been identified by Mr. Barrow as similar to a rock described by him occurring in the Moine Schists of the East Central Highlands. Numerous pebbles of felspar have been examined by the author, and in each case found to be perfectly fresh microcline, the cross-hatching being beautifully clear. Pieces of pegmatite, the constituents being quartz and microcline, are very common in all the beds, but most abundant in the Kinderscout Grit and Rough Rock. Some fragments obtained from the Plompton Grit at Knaresborough proved to be a peculiar silicified oolitic rock, the outlines of the oolitic grains being traced out by small rounded bodies stained red or brown. A few pebbles show undoubted traces of organisms such as sponge spicules, etc.

The heavy minerals of the grit are not numerous, the most plentiful being zircon and garnet. The felspar in the grit, both large and small, are quite fresh when first exposed, and this suggests either disintegration of the parent rock by differences of temperature and rapid transportation, or comparative absence of carbon dioxide in the atmosphere. The author has been much impressed by the many points of similarity existing between the Millstone Grit and the Torridon Sandstone, and is disposed to think that areas of similar rock types were laid under contribution for each.

III.—The Silurian Inlier of Usk.[1] By C. I. Gardiner, M.A., F.G.S.

The Usk Inlier is roughly oval in shape, measuring about eight miles and a half from north to south and four miles from east to west. It is crossed by an important east and west fault, which divides it into two nearly equal parts. The southern half is composed of two anticlines separated by a fault. The axes of these folds run roughly north and south, and dip southwards. The western anticline is the larger of the two, and shows Wenlock Shales and Limestone and Ludlow Beds; these are all very fossiliferous.

[1] Abstract of paper read before the British Association, Section C (Geology), Dundee, September, 1912.

The anticline has been much broken by faulting, and the limestone is now in twelve separate parts. Careful observations of the dips prove faulting to be a satisfactory explanation of this separation. The Silurians are separated from the Old Red Sandstone to the west, from Littlemill to Trostra, by a fault, but from Trostra to Llandegveth and Graigwith the basement bed of the Old Red Sandstone, a yellow quartzose sandstone, rests with apparent conformity on the Ludlow Beds. The eastern anticline is thinner than the western one. Its lowest bed seen is the Wenlock Limestone of Cwm Dowlais, this being covered by Ludlow Beds, which run south through Llangibby Park. A fault line separates these Ludlows from the Old Red Sandstone to the east. The Wenlock Shale is a brown sandy shale where its lowest beds are seen in the railway cuttings near Bryn, and it becomes more sandy in its higher parts, a definite sandstone occurring close to its summit. The Wenlock Limestone has about 12 feet of massive limestone at its base, largely formed of crinoid fragments, and, above this, irregularly bedded limestone separated by thin shaly partings. Corals are scarce, Brachiopods and Trilobites common. The Ludlow Beds are, for the most part, brown sandy shales, with calcareous nodules or thin calcareous layers, but towards their summit they pass up into sandstones. The northern half of the Inlier is far less simple than the southern in its structure, and is more concealed by drift. Its western boundary is everywhere obscured, but Ludlow Beds are seen here and there dipping towards the Old Red Sandstone not far off the boundary. The central part is composed of Wenlock Shale, and the eastern margin is composed of Ludlow Beds dipping eastwards and faulted against the Old Red Sandstone. The Wenlock Limestone is not met with in this northern half of the Inlier. The simplest explanation of these facts is that the Wenlock Shale is faulted against the Ludlow Beds on both sides. As the Aymestry Limestone is absent from the district, it seems impossible to separate the Ludlow Beds into an upper and lower division, but fossils have been carefully collected in order to see if any horizons can be fixed. The main boundary faults are crossed at several spots by minor east and west faults, which cause small lateral displacements.

REVIEWS.

I.—The Making of the Earth. By Professor J. W. Gregory, F.R.S., D.Sc. 16mo; pp. viii, 256, with 37 text-illustrations. London: Williams & Norgate (Home University Library Series), 1912. Price 1*s*. net.

A HIGH standard has already been attained by the Home University Series, and the little volume now before us will command a place among the best. In the small space at his disposal Professor Gregory tells us the story of our earth from the nebula to the appearance of life, and tells it in a style that has a distinct charm, and within his pages we find accounts of the most important and up-to-date theories concerning our earth. The discussion of the nature of nebulæ leads on quite clearly to the stating of the planetismal hypothesis, with which, further, the evidence of ancient climate is shown to be in agreement. In a clear way, too, Professor Gregory traces the formation of the earth's surface, and in a short chapter shows what earthquakes tell us of the interior of the earth. The geographical distribution of extinct animals and plants is dealt with in an interesting manner in connexion with the inconstancy of oceans and continents, and the discussion of the distribution of land and sea leads on to a luminous account of the tetrahedral theory of the earth. The chief points in the earth's history through the various geological periods are then dealt with, and the geographical elements are traced in the existing continents and oceans.

Having considered the main stages in the making of the earth, Professor Gregory proceeds to discuss the biosphere, and finishes his sketch with a delightfully speculative chapter on 'Protobion'—the first living being on the earth. At the end of the book is a Bibliography—in this case a particularly useful inclusion. The writer of the geological volume for this series held a peculiar responsibility, and we feel that in the present work Professor Gregory has done much that will help his readers to think geologically.

II.—The Building of the Alps. By T. G. Bonney, Sc.D., F.R.S., Emeritus Professor of Geology, University College, London. 8vo; pp. 384, with 32 plates and 16 text-illustrations. London: T. Fisher Unwin, Adelphi Terrace, 1912. Price 12*s.* 6*d.* net.

IN this handsome volume, printed in large type, light in weight, and admirably illustrated, Professor Bonney gives us a clear exposition of the petrography, general structure, and mode of formation of the great Alpine mountain region, followed by a description of the Glacial phenomena and by remarks on some Alpine topics of modern times. That he has come well-grounded to his task may be judged from the fact that since 1856 he has spent an amount of time upon it equal to nearly three years—in the earlier visits in walking and climbing and observing more particularly the effects of ice-action, in later visits (since 1880) in the investigation of rock-structures in the field, supplemented by home-studies of the materials under the microscope.

In his opening chapter the author deals with the geographical distribution of the rocks, which may be broadly grouped into the crystalline and the obviously sedimentary. The oldest crystalline rocks consist of gneisses and mica-schists, and these are followed by a group of foliated rocks, comprising mica-schists, quartz-schists, crystalline limestones, with serpentine, hornblendic and chloritic rocks. Intrusive in these rocks are coarse granitoid gneisses which often form a central position as the backbones of the higher mountains. The loftier peaks and more prominent ridges are all formed of the great series of crystalline rocks; the sedimentary rocks in only one instance attaining a height of 13,000 feet, in the limestone peak of the Eiger.

Avoiding so far as possible the use of technical terms, the author briefly explains the origin of the crystalline rocks, all of which had undergone great mechanical and chemical changes and assumed a foliated condition prior to the vast movements that led to the elevation of the mountains. He does not deny the possibility that some gneisses may have been produced by the metamorphism of sediments, but he knows of no conclusive instance. He recognizes a great break between the earliest of the sedimentary rocks and the older gneisses and schists, remarking that the former have not advanced in metamorphism beyond the stage of phyllite, or, in other words, of slate wherein mica is so abundant as to give the rock a peculiar silky lustre.

Ordovician strata are the oldest representatives of the Palæozoic series that have been identified in the Alps, and of these and succeeding formations the author gives brief descriptions. It was not, however, until the end of the Eocene, or quite early in the Oligocene period, that the making of the Alps began, and the process was continued towards the close of the Miocene and into the Pliocene period.

In the course of his chapter on the Materials of the Alps the author discusses the 'difficult question' of certain reported examples of crystalline schists of Silurian, Carboniferous, Triassic, and Jurassic ages. While in certain instances, as he admits, the evidence is inconclusive, yet in others the facts are capable of explanation, and can be attributed to intense folding and overthrust faulting, or to the derivation from older crystalline rocks of mica, garnets, and staurolites. The supposed fossil plants observed in gneiss are now regarded as pseudo-organisms.

In dealing with the great flexures and thrusts which have affected the Alps, we are not surprised to learn that he hesitates to accept all the disturbances "on a scale so gigantic as is demanded by certain enthusiastic advocates of the overthrusting process".

The relations between different types of rock and mountain forms are discussed in an interesting chapter in which the work of Ruskin receives appropriate commendation.[1] The subject too is well illustrated by many of the photographic views and by figures in the text.

Nearly one-third of the volume is occupied by descriptions and discussions concerning the snowfields and glaciers, topics that had been considered by the author in 1865 in a work entitled *Outline Sketches in the High Alps of Dauphiné*, and three years later in *The Alpine Regions of Switzerland and the neighbouring countries*, as well as in separate papers on Cirques, Lakes, and Glacier-Erosion, etc. Here, and also in the descriptions of the rock features, we feel the want of maps, the only important omission among the illustrations in this book.

The making and movement of glaciers and their extension in ancient and modern times are subjects less controversial than those dealing with the sculpturing of the land, the shaping of peaks and valleys, corries or cirques, and the excavation of lake-basins. The author's early conclusions are not modified, namely, "that the work of glaciers is, as a rule, not more than abrasive, and is erosive only under special circumstances." Nevertheless, while the volume is intended to embody the results of his personal observations and researches, he has indicated throughout fairly, and perhaps with more suavity than of old, where different conclusions are held.

There are chapters on Alpine Meteorology, on the Vegetation, and on the Wild Animals of the Alps, and it is interesting to know that the brown bear, wolf, and lynx survive in certain areas. Interesting also is the account of the Alps in relation to Man. It is remarked that the Palæolithic hunter may have wandered into the mountains in pursuit of game, but though he has left a few relics of his presence

[1] See Ruskin, "Shape and Structure of the Alps": GEOL. MAG., 1865, pp. 49 and 193.

in the lowlands, none have occurred, so far as the author knows, within the Alpine margin. Lake dwellings, and the ancient routes and passes traversed in Roman and later times, some of the battles, and the changes undergone in later years, are described; and finally the author relates his personal experiences of fifty years of change, lamenting the injury done by the plunderers of plants, the hooligans, and the advertisement fiend.

Two short appendices contain (1) a few biographical memoranda by the author and a list of his papers on Alpine subjects, and (2) explanatory notes on the full-page illustrations. The index occupies but four pages, and is far too meagre and inconsistent: thus, while the names of Garwood, Ramsay, Sollas, and Penck are given, no mention is made of Fraas, Von Hauer, Heer, Heim, Rothpletz, and some others who are referred to in the text.

III.—Geological Survey of Canada.

The Summary Report of the Geological Survey Branch of the Department of Mines for 1911 (Ottawa, 1912) contains many matters of general interest.

In the course of his special report the Director, Mr. R. W. Brock, makes some comments on the *difficulty of retaining capable scientists*, and the urgency for securing more rapid promotion and higher salaries for the scientific staff. "The loss of an experienced officer is irreparable; for he has in his work secured a mass of detailed information concerning the districts in which he has been engaged that can never be embodied in a report, but that is of constant value to the Department and the public in answering inquiries concerning particular areas or special problems." The same unfortunate state of affairs prevails on the Geological Survey in Great Britain in reference to the officers who hold the rank of Geologists.

More than forty short reports by various officers are given on the Staff Field work, and it is interesting to learn that Dr. C. W. Walcott, Secretary of the Smithsonian Institution, and formerly Director of the United States Geological Survey, has accepted the honorary position of Collaborator in Geology with special reference to the Cambrian. He contributes a report on the Cambrian of the Kicking Horse Valley, British Columbia, giving sections and lists of fossils from the Burgess Shale of the Stephen formation. (See Dr. Peach's address, Geol. Mag., October, p. 457.)

Mr. A. C. Lawson reports on the Archæan rocks of Rainy Lake, Ontario, and announces the discovery of fossils in the limestones of the Steeprock Series, which rest unconformably on the Keewatin. These fossils (not at present described) are said to be "the oldest well-defined organic remains now known to science".

Other reports deal with the Lower Palæozoic and Devonian rocks, with the igneous rocks of Belœil and Rougemont Mountains in Quebec, with raised beaches and changes of level, and with sundry economic accumulations, including clays, oil, gas, gypsum, coal, graphite, mica, apatite, tungsten-ore (scheelite), silver, cobalt, and copper ores, and the occurrence of minute diamonds and rubies.

IV.—Records of the Geological Survey of India.

FIVE contributions on various subjects appear in the first part of the forty-second volume of the *Records* (1912). Of these, one "On the Survival of a Miocene Oyster in Recent Seas", by Messrs. R. B. Newton & E. A. Smith, contains descriptions of some large oysters found during excavations in a recent deposit in Clive Street, Calcutta. These shells, characterized by their great height and extensive development of the ligamental area, are the same as a form still living in the Sunderbands and elsewhere. Their special interest lies in the fact that they have been proved identical with the Miocene *Ostrea gryphoides* (Schlotheim), generally known by the name *crassissima* of Lamarck. A new variety, *cuttackensis*, a shell less prolonged and having a deeper lower valve, is described, and the paper is illustrated by eight very fine plates. Mr. Cowper Reed's paper on Silurian fossils from Kashmir deals mainly with Brachiopods and Trilobites, which are poorly preserved, only the internal casts or traces of external ornament remaining. These have been determined as almost certainly of Llandovery age, and one new form, *Acidaspis kashmirica*, is described. A list of species is given, the determinations of which are fairly certain since they can be compared with European material in a similar condition. The note on specimens of Blödite from the Salt Range, by Mr. Cyril Fox, contains chemical and crystallographic details and is illustrated by one plate.

The occurrence of gold in the alluvial deposits of Mong Long, Hsipaw State, Northern Shan States, is the subject of a report by Mr. J. C. Brown. The gold occurs in thin laminæ and scales, associated sometimes with 'ultra' nuggets, but results of assays show that the deposits are not worth large-scale exploitation. The paper, which is illustrated by three plates, contains full details of the streams examined, and gives a table showing the distribution and area of the auriferous gravels. The last paper in this part is by Mr. C. S. Middlemiss, and places on record the discovery of large deposits of steatite in the Idar State.

The second part of the same volume contains the General Report of the Survey for 1911, with which is issued an account by Professor A. C. Seward of some dicotyledonous leaves from the Assam Coal Series at Margherita. The specimens were sent to the Survey in the hope of furnishing evidence of the age of the Assam Series. The data are insufficient, however, to warrant any decisive statement, but Professor Seward inclines to the view that they belong to a Tertiary rather than to a Cretaceous flora. The leaves are referred provisionally to the genus '*Phyllites*', and two new forms are described—*P. kamarupensis*, n.sp., an oblong-elliptical leaf, about 20 cm. long, with strong midrib and entire margin, and *Phyllites* sp. (cf. *Nerium* spp.). The leaves have a superficial resemblance to recent species of *Magnolia*, but there is a difference in the secondary veins. Professor Seward takes the opportunity of criticizing the frequent attribution of Cretaceous and Tertiary leaves to *Magnolia*, because in many cases the reasons given are altogether insufficient. He contends that many determinations of fossil Angiosperms are of little value as botanical records, and thinks that critical revision of existing lists is highly desirable.

The second paper in this part is by Captain Grinlinton, and consists of "Notes on the Poting Glacier, Kumaon Himalaya, June 1911". This glacier was visited in October, 1906, by Messrs. Cotter and Brown, of the Survey, who at that time noted the position of the snout. The main object of the recent examination was to collect any evidence that might be available as to secular change. Results show the snout to be in much the same position as in 1906, and the most striking features observed were in the left lateral moraine, which exhibits signs of great activity. The paper furnishes interesting details as to the condition of the ice, and is illustrated by eight plates, chiefly of diagrams.

V.—South African Geology. By E. H. L. Schwarz, Professor of Geology at the Rhodes University College, Grahamstown, South Africa. 8vo; pp. vi, 200, with 54 figures. London: Blackie and Son, 1912. Price 3*s*. 6*d*. net.

PROFESSOR SCHWARZ tells us in the preface to this little book how in one of his lectures a roar of laughter greeted a remark to the effect that in the desert springs have no brooks. The humorous aspect is apparent after the explanation that "the only brooks that the South African student knows of are the Dutch equivalent for trousers". The Professor was well acquainted with the difficulties with geological nomenclature experienced by the South African student, but this episode decided that there should be no further delay in the production of a small volume dealing with geology from the South African standpoint. We can quite comprehend that what *not* to include would be a troublesome consideration in the preparation of a work of this kind, but another, the author tells us, was that the book had to be orthodox! We do not think, however, that he errs very much in including an account of the planetismal hypothesis.

The book is divided into four sections, dealing with descriptive, dynamic, tectonic, and stratigraphical geology, the last occupying nearly one-half of the book. The account of volcanoes is good, and we are glad to see reference to the results of Brun's investigations. Throughout the book Professor Schwarz considers facts in relation to their causes, and aims at giving "some insight into the processes of geological reasoning", but in some places his diction is loose. Thus, the statement (p. 82) that "the cause of volcanic action is undergoing revision" evidently is not expressive of the author's true meaning. Seven pages of woodcuts (of Bokkeveld, Karroo, Uitenhage, Stormberg, and Pondoland fossils) and two restorations of reptiles illustrate the palæontology of the various areas described in the stratigraphical section. The legends of some of the woodcuts, we note, require revision, *Tancredia* for *Meyeria* and *Exogya* for *Exogyra* (both on p. 168) being obvious misprints. It would have been better, moreover, to append in every case to the names of the fossil plants figured some indication of the particular structure represented. Are we to regard the omission of an index as an indication that the publisher intends the book to be learnt by heart?

VI.—The Water Supply of Surrey, from Underground Sources, with Records of Sinkings and Borings. By William Whitaker, B.A., F.R.S.; with contributions on the Rainfall by H. R. Mill, LL.D. 8vo; pp. v, 352, with rainfall map; cloth. London, 1912. Price 7*s.*

SINCE his retirement, some years ago, from the public service, Mr. Whitaker has not ceased to devote much time in the interests of the Geological Survey, and his volume of the *Water Supply of Kent* (noticed in the Geological Magazine for 1909, p. 180) has now been followed by a volume nearly as extensive and quite as exhaustive on the *Water Supply of Surrey.*

The old county division is retained, consequently the records include those relating to the boroughs of Wandsworth, Battersea, Lambeth, Camberwell, Southwark, and Bermondsey, that are now part of the county of London. The geological formations which are water-bearing comprise the Drift gravels and sands, Bagshot Beds, Blackheath Beds, Thanet Sand, Chalk, Upper and Lower Greensand, and Hastings Beds.

Accounts are given of the various springs which issue from these formations, including the mineral waters, of which those of Epsom are the most noted. A short description follows of swallow-holes, and full particulars are then given of the intermittent streams or bournes. The Mole has always attracted much attention. When the stream is full, as in winter-time, some of the water finds its way into swallow-holes in the Chalk by the side of the stream; in dry times, as in summer, the stream enters the Chalk tract from the south; but as the underground water-level sinks below the level of the river-channel in places, the stream water is largely absorbed, and the channel becomes dry here and there with occasional pools. Records of the famous Croydon Bourne are given mainly on the authority of Mr. Baldwin Latham, supplemented by personal and other observations.

Remarks are made on the effect of pumping on wells and springs, and on the subject of contamination. The public and private supplies of water taken from springs are few, nearly all the water being obtained from wells and borings, except in the north-eastern part of the county, which is supplied by the Metropolitan Water Board.

Of the wells and borings the deepest is at Ottershaw Park, Chertsey. It was carried through Bracklesham Beds to the base of the Gault, and Lower Greensand was reached at a depth of 1,556 feet. From this formation water overflowed at the surface at the rate of 132,000 gallons a day. The occurrence of the Lower Greensand below ground at this locality strengthens the view of the author that the formation on this westerly side of the London Basin may be continuous to the northern outcrop.

Details of wells and borings occupy 185 pages (including some addenda). Numerous analyses of waters are given, and in a section entitled Miscellaneous there are remarks on the relation of ground-water to disease, mainly by Mr. Baldwin Latham; notes on gases in wells and well-waters; and statements on the Law of Underground Water with especial reference to the county. A bibliography and excellent index complete this important and useful work.

VII.—Oil-finding: An Introduction to the Geological Study of Petroleum. By E. H. Cunningham Craig, B.A., F.G.S.; with an introduction by Sir Boverton Redwood, Bart. pp. xi + 195. London: Edward Arnold, 1912. Price 8*s.* 6*d.* net.

OWING to the greatly increased employment of petroleum of late years, its production and mode of occurrence in the earth's crust have naturally attracted considerable attention. Mr. Cunningham Craig's book should, therefore, prove of interest to a wide circle of readers. The author very properly points out the erroneousness of the supposition that the petroleum industry can be practically considered apart from scientific considerations, and that the finding of petroleum in a given area ought not now to be a matter of mere speculation. His treatment of the subject is bold, and he expresses his opinions strongly and clearly; and, although these may not be generally accepted, they may at least have the good effect of stimulating discussion.

Unlike previous writers, Mr. Cunningham Craig regards the origin of petroleum as the question of vital importance, and to which all others must be subsidiary. The arrangement of the book is in keeping with this standpoint; the discussions throughout are logical, and the appeal to facts frequent; but as regards these facts much must depend on their selection. Of the various theories that have been advanced to account for the origin of petroleum, the author is a special pleader for that which ascribes it to terrestrial vegetation. He admits that the frequent association of salt and brine with petroleum is difficult of explanation in the face of his theory; still, with respect to this point he thinks that future research will produce results of the greatest importance. His present opinion, however, is that the association is accidental. Separate chapters are devoted to processes of formation, migration, subterranean storage, and geological structure, and the author emphasizes the importance of the study of lateral variation, by which alone can oil-forming and oil-bearing conditions be recognized. Useful hints as to field and indoor work are given in the last two chapters. These, although intended for beginners, might well be consulted by persons of more experience. The book is illustrated by thirteen plates of photographs, chiefly of scenes in Burma and Persia, and is furnished with a copious index.

VIII.—The Sedimentary Deposition of Oil. By Murray Stewart, D.Sc., F.G.S.

THE author of this pamphlet, which is reprinted from the Records of the Geological Survey of India, vol. xl, pt. iv, pp. 320–33, 1910, is one of the comparatively few British geologists who have had much opportunity of studying the occurrence of oil in the field. He here puts forward an interesting theory concerning the origin of oil.

Commencing with a statement in favour of organic origin, he proceeds to discuss the well-known but unexplained property possessed by clay whereby it is able to absorb oil and hold it under water. Several interesting quantitative experiments were performed, and it was found on shaking up clay and water and adding oil that 66 grammes of clay sediment took down with it on settling all the oil up to the amount of 14 c.c. The clay and oil used were both from the Yenangyoung Oilfield of Burma. When an American oil, much lighter and of much less viscosity, was used a still greater absorption occurred.

Microscopic examination of the oily sediment showed that the oil was not imprisoned as oily films upon the grains, but "was merely mechanically mixed with the sediment, and that it was the small size of the shale particles that made it impossible for the globules of oil to escape between them and so reach the surface". The limit to the quantity of oil which can be held is reached "when the percentage of oil globules in the whole mass of particles is so great that the oil globules are almost in contact". This varies with the size of the globules, which in turn is dependent on the viscosity.

"The deposition of oil is purely a matter of gravitation." The oil becomes mechanically mixed with the sediment in the form of globules. The oil is unable to separate out, because it is not miscible with the wet mud particles, which part them and prevent them from coalescing.

"The mixture of sediment and oil, being still of higher specific gravity than the water, falls to the bottom and is deposited as a sedimentary deposit."

We think Dr. Stewart's explanation of the absorption of oil far preferable to those put forward hitherto wherein some mysterious affinity between oil and clay was assumed; but we think that the physicists could throw still further light on the problem, and that the question of whether shale particles would be coated by oil under water, or whether globules of oil would be coated with specks of shale, or whether the globules become merely mechanically imprisoned, may be dependent upon the various surface tensions between the liquids and solid concerned. Some readers probably will consider that flowing water would have to be unusually highly charged with mud for oil to be carried down in the manner described.

In the later pages of the pamphlet it is suggested that in oil-bearing formations "oil is of sedimentary origin and is not a secondary product in deposits"; the decomposition of the organic matter (mainly vegetable) has occurred in closed lagoons and swamps "under bacterial action, the oils so formed rising to the surface and forming a layer of oil". At times the oil would find its way into the rivers and ultimately would be deposited in the manner described above. Later, as other strata accumulated above, a certain pressure would be reached for each bed of clay, when the oil would be squeezed out and would find its way into the seam of sand lying next above. The author considers his theory more satisfactory than others, because it "does not require any supposed removal of either nitrogenous matter or the fibrous tissues of plants, neither does it require the assumption of bacterial action deep underground in the presence of salt water".

We think that some field evidence is desirable to support this interesting idea. The present writer has seen something of tropical lagoons in the quest of oil, but he has not seen oil films on any of them (except where oil rock crops out beneath). If such a phenomenon does occur it certainly is either invisible or unusual. The author is careful, however, to point out that he does not wish to apply his explanation of the formation of oil to every case.

T. O. B.

IX.—Cotteswold Naturalists' Field Club.

We have before us part iii of vol. xvii of the Proceedings of this Club. It contains records of sundry excursions, including one to Cirencester (with a view of the Royal Agricultural College), and another to Brecon (with views of the Brecon Beacons, Llangorse Lake, etc.). The original articles are mainly geological. The indefatigable secretary, Mr. L. Richardson, contributes a "Memoir explanatory of a map of part of Cheltenham and neighbourhood, showing the distribution of the sand, gravel, and clay". The map is a colour-printed geological edition of Sheet 26 N.E. (Ordnance six-inch map). The amount of detail is not great, but the map clearly shows, by means of six tablets and colours, the distribution at the surface of Lower and Middle Lias clays, and Drift gravel, sand, and bog. The reproduction of the map must have been costly, but it should be of practical service. Details of the strata and their fossils are given in the memoir, the materials having "been acquired little by little over a period of at least ten years". There is an analysis of Lower Lias clay, also notes on economic uses of the deposits, their soils, and supplies of water; and there are illustrations of brick-works, clay and sand-pits. Dr. J. H. Garrett supplies an appendix "On the Local Waters of the Town of Cheltenham". The mineral waters are of especial interest, as coming from the Liassic clays, and from the fact of "the quality of the yield of no two wells being alike, but often quite distinct and different, though the wells be only a short distance apart".

Dr. E. A. Newell Arber is author of a paper on "The Fossil Plants of the Forest of Dean Coalfield", illustrated by three plates. The floras of the productive strata all belong to the Upper Coal-measures; and they include forty-four species, all known to occur elsewhere in Britain. The author observes that "The Forest of Dean is not an outlier of the South Wales coal-field, as has often been supposed. It is more closely related to the Radstock and Bristol coal-fields. There are no equivalents in the Forest of Dean of the Middle Coal-measures (White Ash Series) or Transition Coal-measures (Pennant Grit) of South Wales, and the massive Forest of Dean Stone belongs to a higher horizon than the Pennant Grit, with which it has been often correlated". These views appear revolutionary, but we have been prepared by Dr. T. F. Sibly (Geol. Mag., 1912, p. 417) for the new interpretation of the structure of the district.

Among other articles is one by Mr. William Bellows on "The Island of Jan Mayen"; one by Mr. Richardson on "The Water Supply of the City of Gloucester"; and one on "The Lower Severn Plain during the Glacial Epoch", by Mr. Joseph W. Gray. In this last paper the author concludes that the deposits "suggest a partial derivation from moraines left by ice-sheets that approached the district on the north and east. Other parts may be remnants of Tertiary river gravels". He further remarks that "Although there may have been an extension of the Severn Estuary as far north as Worcester, there is no evidence of a great Post-Cretaceous submergence of the whole of the Plain".

X.—Prehistoric Society of East Anglia.

In the Geological Magazine for November, 1911 (p. 522), we drew attention to the first part of the Proceedings of this Society. The second part, for 1910–12, has just been issued (H. K. Lewis, 136 Gower Street, W.C., price 3*s.* 6*d.* net). It contains abundant material concerning flints variously shaped, some by nature, most of them regarded as 'artifacts' or not manufactured by nature. The several papers are illustrated by no less than thirty-one plates, some of undisputed Palæolithic and Neolithic implements, scrapers, flakes, and cores, others of the partially chipped or unchipped flints that may have been found serviceable by man or "some intelligent ape-like progenitor".

Dr. W. Allen Sturge writes on "The Patina of Flint Implements", Mr. J. Reid Moir on "The Natural Fracture of Flint and its bearing upon Rudimentary Flint Implements", and Mr. F. N. Haward on "The Chipping of Flints by Natural Agencies". The views expressed are not all favourable to the great antiquity of man, nor to the evidence of his handiwork on some of the ruder types of so-called implements. Considering that there is doubt about the presence of man in Pliocene times, it would be preferable not to use so definite a title as that on "Implements of Sub-Crag Man in Norfolk", by Mr. W. G. Clarke. "Sub-Crag Implements" would be better, as it would allow of the agency of an anthropoid animal. It is indeed remarked by Mr. Moir that "The biologists have no evidence as to when Man first appeared on this earth, and in my opinion are quite absurd in drawing conclusions regarding him from the other mammalia". This is not a philosophical statement. Mr. Haward, in discussing the "interesting and problematic chipped stones called Eoliths", concludes "that the vast majority of these meaningless chipped flints are the result of Nature's work and not Man's". A full account of "The Occurrence of a Human Skeleton in a Glacial Deposit at Ipswich" is given by Mr. Moir, and one of the remarkable points mentioned is that "the skeleton was lying partly embedded in glacial sand and partly in boulder-clay". If true, this seems inexplicable. The "boulder-clay", however, was a weathered and decalcified brown loam, and the geologists who have given testimony could not express opinions whether or not there had been evidence of interment.

In Dr. A. Keith's "Description of the Ipswich Skeleton" (with illustrations) he refers to the Heidelberg jaw and the fossil man of Java, observing that "the Ipswich man differed profoundly from both of these, and in every point in which he differs from them he approaches modern man". Further and more precise evidence is required, and although we agree that many rude pre-Palæolithic or Eolithic implements may have been utilized by man in early Pleistocene times, we have yet to be convinced that he lived in Britain during the Pliocene period.

NOTE.—Several references have already been made to the Ipswich skeleton: see article by G. Salter, GEOL. MAG., April, 1912, pp. 164–9; letter by Professor T. McKenny Hughes, F.R.S., April, pp. 187–8; letter by J. Reid Moir, May, pp. 239–40; Report Royal Anthropological Institute, June, pp. 287–8.

XI.—BRIEF NOTICES.

1. UNITED STATES GEOLOGICAL SURVEY.—From this institution we have received a list (pp. 116, with good index, 1912) of all the serial publications of the Survey, including Annual Reports, Monographs, Professional Papers, Bulletins, Water-supply and Irrigation Papers, Mineral Resources, Topographic Atlas (folios and separate sheets), and Geological Atlas (folios). The list is complete to date, except as regards the particulars of the topographic maps and authors of both memoirs and maps are recorded.

2. GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.—The Annual Progress Report of this Survey for 1911 (Perth, 1912) by the Government Geologist, Mr. A. Gibb Maitland, contains brief records of the work done in the field, office, and laboratory. It is noted that samples of fergusonite (tantalate of yttrium) from Cooglegong prove to be of economic importance, and may lead to an industry for the preparation of tantalum salts. Since the new radio-active mineral, pilbarite, was discovered at Wodgina, two further minerals containing uranium, radium, and thorium have been found in the same lode. These may be identified with mackintoshite and thorogummite, previously recorded from Texas. All three minerals are of high commercial value.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

November 6, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "A Contribution to our Knowledge of Wealden Floras, with Special Reference to a Collection of Plants from Sussex." By Albert Charles Seward, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in Cambridge University.

In this paper an account is given of specimens of Wealden plants from the Sussex coast, for the most part from the neighbourhood of Fairlight, acquired by the British Museum since 1895, the date of publication of the second part of the Wealden Flora (British Museum Catalogue). The majority of the fossils have been presented to the National Collection by Father Félix Pelletier and Father Teilhard de Chardin, by whom they were collected, and who worked in association with Mr. Charles Dawson, F.S.A., F.G.S.; the remainder form part of the Rufford Collection. Fresh information is given in regard to several previously recorded species, and the following new types are described: A new species of *Lycopodites* (a lycopodiaceous plant with the habit of a *Selaginella*); a new species of *Selaginellites*, which affords evidence of heterospory; a new species of *Hausmannia*, founded on several well-preserved fronds; a new genus and species represented by incomplete fertile pinnæ with well-preserved spores very similar to those of recent Schizæaceæ; a new genus and species of fern founded on fertile pinnæ; *Aphlebia* sp.; a new species of *Dichopteris*; *Ctenis* sp.; a new species of *Conites*; *Pinites* sp., cf. *P. dunkeri*, Carr. Additional information is given in regard to the following species: *Sagenopteris mantelli* (Dunk.), *Matonidium gœpperti* (Ett.), *Ruffordia gœpperti* (Dunk.), *Cladophlebis browniana* (Dunk.), *Williamsonia carruthersi*, Sew. (?), *Otozamites klipsteini* (Dunk.), *Eurycycadolepis* sp., *Araucarites pippingfordensis*, Ung., *Pinites solmsi*, Sew., and *Sphenolepidium kurrianum* (Dunk.).

The concluding section deals with Wealden floras generally, and some account is given of the geographical distribution of the better-known types. It is pointed out that, while there is a very close similarity between the Wealden flora of England and the corresponding floras in Eastern and Western North America, the number of cosmopolitan types is less than in the case of the Middle Jurassic floras.

2. "Notes on the Discovery of Fossiliferous Old Red Sandstone in a Boring at Southall, near Ealing." By Ernest Proctor, A.R.C.S. (Communicated by Professor W. W. Watts, Sc.D., F.R.S., V.P.G.S.) With a Note on the Fish-remains, by Dr. A. Smith Woodward, LL.D., F.R.S., Sec.G.S.

The boring described in this paper is situated at Southall, and was made for the purpose of obtaining water from the Lower Greensand. For this purpose, however, the boring was a complete failure, as it passed directly from the Gault into Palæozoic rocks. The older rocks were met with at a depth of 1,130 feet, and continued with slight variation to a depth of 1,261 feet, the lower limit of the borehole. For the most part they were red and green mottled clays and sandstones, with occasional bands of fine conglomerate.

The fossils were yielded by definite bands, which varied from 1 inch to an eighth of an inch in thickness; they consisted mainly of scales and teeth of *Holoptychius* and plates of *Bothriolepis*, both characteristic genera of the Old Red Sandstone.

The paper concludes with a brief description of the fish-remains, which, although fragmentary, are sufficient to indicate the Upper Devonian or Upper Old Red Sandstone age of the rocks in which they were discovered.

CORRESPONDENCE.

PROFESSOR BONNEY AND THE LATE COLONEL GEORGE GREENWOOD.[1]

SIR,—In justice to the memory of one who has been long departed, but a former writer in the GEOLOGICAL MAGAZINE, I trust you will allow me to enter a strong protest in your pages against the manner in which Professor Bonney has treated the work of my uncle, the late Colonel George Greenwood, in the book he has recently published under the title of *The Work of Rain and Rivers*, one of the Cambridge Manuals of Science and Literature.

Colonel George Greenwood published his work, *Rain and Rivers*, in 1857, at a time when geological opinion had by no means emancipated itself from the doctrines and dogmas of the *cataclysmic* and *catastrophic* school. He was one of the very first to argue in support of the "doctrine of continuity", maintaining that the present aspect of the globe is due to causes still at work, and which have been acting for an immeasurable period of time. He was, in fact, a pioneer of the doctrine of "evolution in the organic world". It was, therefore, with great appropriateness and entire justice that the late Mr. Mackintosh styled him "the father of modern sub-aerialism" (GEOL. MAG., 1876, p. 572).

I maintain, therefore, that Colonel George Greenwood is entitled to very honourable mention in the history of geological thought. But how is he treated by Professor Bonney? The Professor first damns him with faint praise, and then dismisses him with a quotation from some unknown 'reviewer' in the GEOLOGICAL MAGAZINE of 1867 (p. 412). Professor Bonney, on p. 132, further says: "It was not until 1862 that the work of rivers in the excavation of valleys was placed beyond question in our own country. For this we are indebted to . . . J. B. Jukes . . ." I should be the last to underrate the debt which is owing to the memory of Mr. Jukes, but what did Professor Jukes say himself in 1863 of Colonel Greenwood's book? He alludes to it as "an excellent little work called *Rain and Rivers* . . . in which the atmospheric origin of all river valleys is advocated in the clearest and most convincing style".

In view of all this (and much more evidence to the same effect could be adduced), I venture to say that Professor Bonney does very great injustice to the memory of the author of a most clearly reasoned and original work. I can only appeal to you, sir, in the interest of historical accuracy, to give this letter a place in the GEOLOGICAL MAGAZINE, and to Professor Bonney to eliminate a passage as ungenerous as it is unjust from the second edition of his Manual. Meanwhile, if this letter could but induce some geological students of to-day to read for themselves the pages of *Rain and Rivers*, they will, I am confident, recognize the justice of the claim which I make on behalf of a remarkable book. GEORGE GREENWOOD.

HOUSE OF COMMONS.
November 19.

[1] [Owing to want of space it has been found necessary to greatly abridge Mr. Greenwood's letter.—ED. GEOL. MAG.]

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All Communications for this Magazine should be addressed—

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