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OR

Monthly Journal of Geology.

WITH WHICH IS INCORPORATED

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EDITED BY

HENRY WOODWARD, LL.D., F.R.S., F.G.S., V.P.Z.S., F.R.M.S.

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

ASSISTED BY

PROFESSOR J. W. GREGORY, D.Sc., F.R.S., F.G.S.
DR. GEORGE J. HINDE, F.R.S., F.G.S.
SIR T. H. HOLLAND, K.C.I.E., A.R.C.S., D.Sc., F.R.S., V.P.G.S.
PROFESSOR J. E. MARR, M.A., Sc.D. (Camb.), F.R.S., F.G.S.
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DR. ARTHUR SMITH WOODWARD, LL.D., F.R.S., F.L.S., V.P.G.S.

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. I.—JANUARY, 1917.

ORIGINAL ARTICLES.

I.—Early Man.

By Arthur Smith Woodward, LL.D., F.R.S.

GEOLOGISTS and archæologists are much indebted to Professors Osborn and Obermaier [1] for useful up-to-date summaries of our knowledge of early man, with extensive bibliographies which include most of the latest papers. So much progress has been made in the study of the subject during recent years—especially since the Prince of Monaco's foundation of the Institute of Human Palæontology in Paris—that synoptical treatises of this kind are an indispensable aid to further advance. Both are also intended, with their beautiful illustrations, to arouse interest in a much wider circle than that of students who are actually engaged in research. They should, indeed, help in urging the educated public to take every opportunity of bringing to the notice of scientific men such casual discoveries of human remains and traces of human handiwork as they happen to meet with. It is lamentable to think how few of these discoveries, even under existing circumstances, are rescued from destruction and made available for study.

Both authors deal with the geological questions involved in determining the relative ages and circumstances of life of the successive races of men who inhabited Western Europe before the dawn of history. Professor Osborn, however, treats these questions at greatest length, and includes an elaborate summary of Penck & Brückner's work, *Die Alpen im Eiszeitalter*, with which he attempts to correlate all the European discoveries of Palæolithic man. He even goes further in assigning dates to the successive episodes which he recognizes, and we cannot refrain from protesting against the false appearance of knowledge which he thus provides for the unwary reader who does not understand geology. "Heidelberg man," Professor Osborn writes, "is nearly twice as ancient as the Piltdown man, while *Pithecanthropus* (Trinil Race) is four times as ancient. Yet the Piltdown man must still be regarded as of very great antiquity, for he is four times as ancient as the final type of Neanderthal man belonging to the Mousterian industrial stage." It is scarcely necessary to add that there is no real scientific basis for any of these statements.

All are agreed that among the remains usually claimed to be

[1] H. F. Osborn, *Men of the Old Stone Age—their Environment, Life, and Art.* New York, Charles Scribner's Sons, 1915 (2nd ed., 1916). H. Obermaier, *El Hombre Fósil.* Madrid, Comisión de Investigaciones Paleontológicas y Prehistóricas, Memoria No. 9, 1916.

connected with the early ancestry of man those of *Pithecanthropus erectus* from Java are probably the oldest hitherto discovered. Professors Osborn and Obermaier, however, differ considerably in their interpretation of this remarkable fossil species, the former regarding it as a lowly type of man, the latter treating it as a gigantic ape. The fact is that no further progress can be made in understanding *Pithecanthropus* until Professor Eugene Dubois publishes his long-promised detailed description of the cast of the brain-cavity which he has so beautifully prepared. During my last visit to Holland, in 1913, Professor Dubois kindly showed me all the original specimens with materials for comparison, and my own impression was that the resemblances to the gibbon which he has pointed out in each part are very real and striking. The upper molar teeth and the distal end of the femur, for example, have some remarkably gibbon-like characters. A detached lower premolar, it is true, is essentially human in type; but the fragment of mandible, from the same geological formation, so often mentioned in notices of *Pithecanthropus*, was found a few miles distant from the other remains and cannot at present be associated with them. This specimen is merely a waterworn piece of bone beneath the two premolars, which have lost their crowns; but, so far as preserved, it appears to be typically human. There is thus some reason to suspect that man himself lived in Java with *Pithecanthropus*, and that the latter was really a gigantic and precocious gibbon. The occurrence of such an animal in the large island of Java—the special home of gibbons—would be precisely analogous to the presence of the extinct gigantic and precocious lemurs in the swamps and caves of the large island of Madagascar—the special home of lemurs.

For some reason which I do not appreciate, Professor Osborn supposes that *Homo heidelbergensis* is next in antiquity to *Pithecanthropus*, while *Eoanthropus dawsoni* (Piltdown man) flourished much later. Such an opinion can only be founded on negative evidence, and the reverse is suggested by the characters of the lower jaw itself. *Eoanthropus* may have survived to become contemporary with Heidelberg man, but it can scarcely have had a later origin. Professor Osborn's own restoration of the skull and mandible of *Eoanthropus* (made with the help of Professor J. H. McGregor) is, indeed, essentially similar to the latest restorations made independently both by the British Museum and by the Royal College of Surgeons, and certainly represents the lowest human type hitherto discovered. Professor Osborn only mars his work by placing the canine tooth in the upper jaw, with no opposing tooth in the lower jaw which could produce its characteristic deep surface of wear. He also fails to recognize the fact that this canine tooth is more closely similar in shape to the lower milk-canine of *Homo sapiens* than to the canine, either upper or lower, whether temporary or permanent, of any known ape. In the second edition of his volume (without, however, altering the main part of the text) he seems to realize the difficulties of his position, and even adopts the strange opinion of Mr. Gerrit S. Miller,[1] that the Piltdown lower jaw and canine tooth do not

[1] G. S. Miller, *The Jaw of the Piltdown Man*, Smithson. Miscell. Collections, vol. lxv, No. 12, pp. 31, pls. v, 1915.

belong to the associated skull but represent a new species of chimpanzee. Mr. Miller does not recognize that the lower molar teeth are essentially human, and his arguments will soon be satisfactorily dealt with by Mr. W. P. Pycraft in *Science Progress.* I hope then to give some account of a discovery made by the late Mr. Charles Dawson shortly before his death, which appears to me to confirm the interpretation of *Eoanthropus* which he and I originally published in 1912.

All the mammalian remains found in the Piltdown gravel are in so fragmentary a condition, and several are so obviously derived from an older stratum, that they are insufficient to date *Eoanthropus* with exactness. Probably the only specimen of real importance from this point of view is the unique bone implement,[1] apparently made from the femur of an elephant which was too large for *Elephas primigenius*, but must have agreed in size with that of *E. antiquus* and *E. meridionalis.* In the Mauer sand, however, in which the lower jaw of *Homo heidelbergensis* was found, mammalian remains are abundant, and many of the specimens shown to me by Professor W. Salomon at Heidelberg in 1912 are in a remarkable state of preservation. As all palæontologists agree, this mammalian fauna must date back to a very early part of the Pleistocene period. The human lower jaw is in the same condition as the other remains, and is evidently of the same age. Compared with the Piltdown jaw it is typically human ; but it differs from later human lower jaws both in the sharp retreat of the chin and in the incomplete bony filling of the ape-like pit on the inner face of the chin where the geniohyoid and geniohyoglossal muscles have their origin.

Since Professor Marcellin Boule's exhaustive memoir on the skeleton of La-Chapelle-aux-Saints (1911–13), nothing of importance has been added to our knowledge of Neanderthal man. Professor Schwalbe has described a lower jaw from Taubach, near Weimar (Germany), and Professor Obermaier makes known another from Bañolas, province of Gerona (Spain). This race, however, is now tolerably well known, while the associated implements and remains of the mammalian fauna are well represented in many collections. Both Professor Osborn and Professor Obermaier are able to give a good account of the circumstances of the Mousterian period during which Neanderthal man lived. There is no doubt that the comparatively genial conditions which surrounded Piltdown man and Heidelberg man had passed away, and that an Arctic fauna predominated.

The chief interest of later Palæolithic man centres, not in his skeleton, but in his artistic attainments; and a large proportion of the two new volumes before us is devoted to a beautifully illustrated account of the discoveries of later Palæolithic art in France and Spain. None but those who have seen them, however, can realize the extraordinary skill with which the drawings and paintings are made on the irregular surfaces of rock in the remote recesses of the

[1] C. Dawson & A. S. Woodward, "On a Bone Implement from Piltdown (Sussex)" : Quart. Journ. Geol. Soc., vol. lxxi, pp. 144–8, pl. xiv, 1915.

caverns. While scrambling through the cavern of Castillo, near Puente Viesgo (Santander), with Mr. Alcalde del Rio in 1910, when its exploration had only been begun, my wife and I had the opportunity of appreciating, not only the skill of the Palæolithic artists, but also the patience of those who have during recent years made so many faithful copies of their work for publication. Professor Obermaier devotes two pages to a discussion of the authenticity of these drawings and paintings, which can only be necessary for readers who have not had the privilege of seeing and considering the originals.

It becomes increasingly clear that man did not reach America until he had attained the grade of *Homo sapiens*, and both Professor Osborn and Professor Obermaier omit the discussion of American fossil man from their story. It can merely be stated that there is evidence both in North and South America of the presence of typical man among the remains of Pleistocene mammals which are now extinct. An interesting case has lately been recorded in the United States.[1] In remote parts of the Old World, however, important discoveries of early man are more hopeful, for only so recently as 1914 a well-fossilized human skull was found in a river deposit containing Pleistocene mammals at Talgai in the Darling Downs, Queensland. It was exhibited to the British Association meeting in Sydney by Professor Edgeworth David and Professor Smith, and it is shortly to be described in a memoir submitted to the Royal Society of London. Photographs of the specimen were shown to the Geological Society of London on December 1, 1915.[2] Although in nearly every respect the skull of a typical Australian aborigine, this fossil agrees with *Eoanthropus* from Piltdown in having the relatively large canine teeth interlocking as in the apes, and it is the only known skull of *Homo* exhibiting this arrangement. The upper canines are typical permanent teeth merely enlarged and modified; the lower canines (still undiscovered) were therefore probably also of the permanent pattern, and thus differed from those of the more primitive *Eoanthropus* which, as already mentioned, are shaped like the modern human milk-teeth.

The unravelling of the story of early man is indeed a continual struggle with the fragmentary evidence of casual discoveries. Much of it still consists in the balancing of probabilities. The value of the influence of attractive summaries like those before us, adapted for the general reader as well as the specialist, cannot therefore be too highly estimated. No one can tell how and where their influence may preserve the next important discovery from thoughtless destruction.

[1] E. H. Sellards, "On the Discovery of Fossil Human Remains in Florida in association with Extinct Vertebrates": Amer. Journ. Sci. [4], vol. xlii, pp. 1–18, with figs., 1916.

[2] GEOL. MAG., Dec. VI, Vol. III, p. 44, January, 1916.

II.—Some Notes on the Post-Eocene and Post-Miocene Movements in the Oilfield Region of Egypt.

By William Fraser Hume, D.Sc., A.R.S.M., F.G.S., Director of the Geological Survey of Egypt.

It may interest readers of the Geological Magazine to have a summarized account of the new data obtained regarding the Post-Eocene and Post-Miocene movements in the Gulf of Suez area, and notably in its southern portion, the oilfield region of Egypt (see Map, Fig. 1).

To understand the subsequent remarks it is necessary to have one or two fundamental conceptions, obtained from previous studies, well established in our minds. The first is the nature of the strata which were present in the region before folding began. Owing to the great depression of Cretaceous times a mass of limestones, clays, and sandstones were laid down on the old solid continental foundation of granites and metamorphic rocks. These soft sedimentary beds may have attained a thickness of at least 2,000 feet.

In the second place, folding at the close of the Cretaceous period (the nature of which is masked by subsequent events) led to the redistribution of much of the upper highly calcareous material, and no doubt supplied the carbonate of lime necessary for the shell-deposits, nummulitic beds, etc., of the Egyptian Eocene. These gave an additional 2,000 feet or more of strata, and it is thus possible that in the basin portions of the Post-Cretaceous fold the sedimentaries may be fully 4,000 feet thick as an average. When examining the total thickness of the Eocene and Cretaceous beds in Egypt for the "Explanatory Notes to accompany the Geological Map of Egypt" I found a maximum of 6,000 feet.

The great primary Egyptian fold is, however, undoubtedly the one which closed the Eocene Period. A glance at the geological map of Egypt exhibits to us the broad shallow synclinal basin of Central Egypt with N.W.–S.E. axis, and it needs but little imagination mentally to picture the corresponding anticline, the central axis of which would lie in the Gulf of Suez and Red Sea. We have thus a region of compression in Egypt proper, but one of tension where the Red Sea now is. In that of tension there would be tendency for the formation of a series of fractures parallel to and including one at the axis. It seems to me that the underlying harder granite-metamorphic complex will break more readily than the more plastic materials overlying it, the result being that spaces will be left beneath the sedimentaries into which these would naturally tend to sink. But in the rising anticline there will also be maximum erosion towards the central axis, so that the Eocene–Cretaceous sedimentaries will be greatly reduced or wholly disappear. The facts are clear enough.

Nearest the centre of the anticlinal axis, on Shadwan Island, for example, the Miocene beds rest directly against the granite, there being no sign of more ancient sedimentaries. In Gebel Zeit, slightly to the west of the probable axis, all the Eocene and uppermost Cretaceous beds have disappeared (being only shown to have existed

MAP OF EGYPTIAN OILFIELD REGION *Fig. 1*

by a flint conglomerate), but we find the Lower Cretaceous strata and Nubian Sandstone between the Miocene and the granite, whereas in Gebel Esh,[1] some 20 kilometres west of Gebel Zeit, the missing Eocene and Cretaceous beds are represented.

The broad space between the Red Sea Hills and Sinai Mountains would, on this view, have originated as the result of a combination of anticlinal fracture and erosion, acting on two media, the lower one of which was, in the main, hard and brittle, the upper one plastic and pliable. The above-mentioned ranges are themselves connected with dislocation-lines of the most pronounced type, the faulted borders in each case being on the sides towards the Gulf of Suez. At the close of the Lower Miocene period there appears to have been a general sinking, as a result of which the waters of the Mediterranean were enabled to invade the above-mentioned groove. The breadth of this greater Gulf of Suez appears to be at its maximum about 70 kilometres, and in it were laid down deeper-water strata, such as Globigerina Oozes, and also others in which various characteristic Miocene *Pecten* species predominate, whilst later these were overlain by a vast series of calcareous gypsum and salt deposits, which in places appear to attain thicknesses of at least 3,000 feet! (a thickness of 6,000 feet is suggested north of lat. 28° N., but the country has not been studied in detail).

The shore-lines of this Miocene arm are well defined by the presence of coral reefs and flint conglomerate beds, the latter representing the erosion of Eocene or Upper Cretaceous beds previously existing.

With the close of Miocene times this triple complex of Miocene beds, older sedimentaries preserved from erosion, and granite-metamorphic rock core, became subject to new compression by which the whole region was thrown into a series of N.W.–S.E. trending folds, in which the anticlines, asymmetrical in character, had their most steeply inclined sides directed towards the Gulf of Suez. Each of these anticlines has determined a well-marked physical feature, the Esh-Mellaha, Zeit, and Araba (in Sinai) Hills respectively. In the simplest case the relation of slope on the two flanks is about 1 to 3 or 4, the general dip on the less inclined limb being 8° to 10°, and on the more inclined one 25° to 35°. As already stated, the resistant centre of the fold system must be along the Gulf of Suez, as the steeper wave-fronts are toward it both to eastward and westward. The effects of the folding are greatly exaggerated where granite forms the lowest known member of the fold. In such instances the granite behaves as though it had been a solid wedge driven through the underlying softer strata; the beds near the granitic apex of the anticline are greatly reduced in thickness, and on the steeper side of the arch in extreme cases are pinched out, or otherwise violently dislocated.

The structure in Gebel Zeit is of interest as an example. In the typical cross-section the central axis of the anticline is formed by the granitic massif, on the western flank of which the immediately

[1] *Gebel* means 'hill' in Arabic.

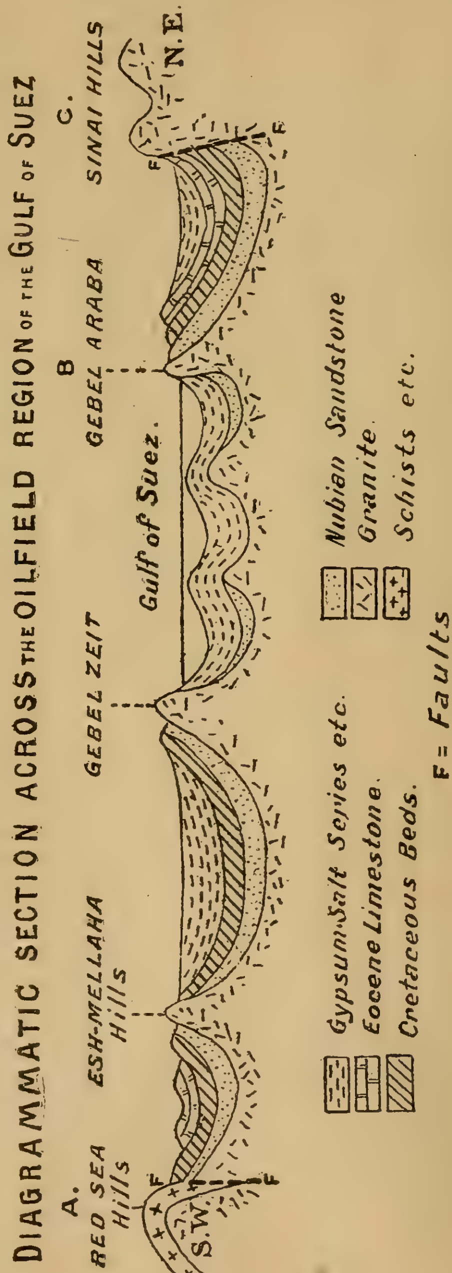
DIAGRAMMATIC SECTION ACROSS THE OILFIELD REGION OF THE GULF OF SUEZ
A.
RED SEA Hills
ESH-MELLAHA Hills
GEBEL ZEIT
B
GEBEL ARABA
C.
SINAI HILLS
Gulf of Suez.
S.W.
N.E.
F
F
F
F
Gypsum Salt Series etc.
Eocene Limestone.
Cretaceous Beds.
Nubian Sandstone
Granite.
Schists etc.
F = Faults

Fig. 2.

overlying Nubian Sandstone is frequently tilted at high angles (60° or over). The succeeding upper sandstones and Cretaceous strata dip westward from the range at an average of 35°, while the overlying Miocene gypsums and clays have their inclination reduced to 20°. The upper beds of the gypsum only dip 10°, and the Pliocene formations capping the series 4° to 6°. The Nubian Sandstone, which on the west flank is some thousand feet thick, on the eastern flank of the range is reduced to an intensely crushed band, only a few yards in width, immediately overlain by gypsum. It is obvious that the comparative horizontality of Pliocene and Miocene beds at the surface may mask highly disturbed conditions in the strata underneath.

Fuller details are about to be issued on these very interesting questions in a "Report on the Oilfields Region of Egypt" now in the press, where the results of the writer's researches in this region during several years have been summarized. In this connexion I might also call attention to the new volume on the *Geography and Geology of West Central Sinai* by my colleague Dr. John Ball, in which some of the fine faulting along the edges of the Gulf of Suez to the north of the oilfield region is clearly illustrated on Plate xvii.

Through the kind permission of the Director-General I am enabled to send a small map and diagrammatic sketch section of the region specially dealt with, which has become of great economic interest on account of the developments of the petroleum industry in two portions of its area. The occurrence has raised a number of interesting physical and chemical questions, which are now being carefully considered, as a large number of analyses of the deep-seated waters have been made in the Egyptian Government Analytical Laboratory, and the results plotted at the Geological Survey.

III.—*Octotremacis*, its Structure, Affinities, and Age.

By J. W. Gregory, D.Sc., F.R.S., of Glasgow University.

The Javan fossil corals collected by the Austrian frigate *Novara* included a specimen on which Reuss (1866, p. 172) founded a new genus, *Polysolenia*. He described it (ibid., p. 172) as showing in the structure of its cœnenchyma "eine überraschende Ähnlichkeit mit *Polytremacis* und *Heliopora*". "Das Cönenchym besteht aus langen, ziemlich dicken, geraden, neben einander liegenden Röhren." These tubes, according to his account, occur in circles of six around a central tube. Reuss repeated (p. 174) that the cœnenchyma is composed of regular parallel tubes (Röhren), whereby it is closely allied to *Heliopora* and *Polytremacis*. He named it *Polysolenia* "nach ihrer röhrigen Structur". Reuss' illustrations suggested some suspicion as to the accuracy of his description, since the dark parts of his figures might be interpreted as the original solid structures of the coral, and the light parts as the matrix. If so, the cœnenchyma would be trabecular and the septa a series of thin lamella. Reuss, however, was emphatic that the septa are thicker than the walls of the supposed cœnenchymal canals; and, if so, the light parts of the figure represent the original solid structures. If the coral had undergone a double change in fossilization Reuss' view was possible; and his statements that the circular rods are casts of canals were so positive that, though in 1900 I mentioned my doubts, I felt bound to dismiss them. So I accepted the fossil as a Miocene Helioporid, and as the name *Polysolenia* was preoccupied renamed the genus *Octotremacis* (1900, p. 302).

A fossil collected by the Right Hon. Sir William Macgregor, G.C.M.G., C.B., etc., from the upper part of the Fly River in New Guinea, shows that my suspicions were justified. This specimen seems to me almost certainly the same species as *Polysolenia hochstetteri*. It agrees very closely with the figures by Reuss, the only noteworthy difference being that the horizontal synapticula are less regularly horizontal than they are there represented. First inspection of the transverse section suggested that in the New Guinea specimen the corallites are considerably larger than in those from Java; but this appearance is due to the section having been cut obliquely. The tubes cut at right angles and the shorter width of those cut obliquely have dimensions very slightly larger than those in *Octotremacis hochstetteri*. In the type of the species the corallites have a diameter of 2 mm., and are from $2\frac{1}{2}$ to 4 mm. apart; whereas in Sir William Macgregor's specimen the diameter is from 2 to $2\frac{1}{2}$ mm. and the corallites are from $2\frac{1}{2}$ to 5 mm. apart. There seems no difference between the corals adequate for their specific separation.

This Fly River coral has, however, clearly a trabecular cœnenchyma, which is composed of parallel vertical rods. Some of the rods project slightly into the tubes of the corallites, and are suddenly reduced in thickness to very thin irregular septa. This specimen shows that the thick vertical structures identified by Reuss as the septa are casts of the interseptal spaces. The septa are the thin intervening lamellæ. According to Reuss their number is eight; but he shows one corallite with seven, and he refers to the occurrence of only six septa. In Sir William Macgregor's specimen the number six is the more common, though specimens with seven and with less than six septa also occur.

As this coral has a trabecular and not a tubular cœnenchyma, its systematic position has to be changed. Instead of being an Heliolitid its affinities are with *Astræopora*. It agrees with that genus in its trabecular cœnenchyma, circular calices, the extreme thinness of the septa, which are absent from some corallites, and the presence of horizontal laminæ, which in vertical sections, as is well shown in Reuss' figure, pl. ii, 3*d*, have almost the aspect of tabulæ. This lamellar structure occurs in many Fungians owing to the development of synapticular platforms. *Octotremacis* may therefore be diagnosed as follows: Madreporidæ with a massive corallum and a loose cœnenchyma composed of vertical trabecula and regular conspicuous horizontal synapticular laminæ. The septa are very thin (but better developed than in *Astræopora*); they vary in number usually from six to eight. No columella. Type, *Octotremacis hochstetteri*, Reuss sp. Eocene, Java.

Whether *Octotremacis* is generically distinct from *Astræopora* is at present doubtful. The characteristic which offers most evidence for their separation is the development of the horizontal lamellæ. The type species of *Astræopora*, *A. myriophthalma* (Lam.), as figured by Bernard (1896, pl. xxvi), appears to be built of tubular corallites with sharply defined walls, to have no septa visible on the surface, and in vertical section to have no regular synapticular platforms. In *A. listeri*, Bern. (ibid., pl. xxviii), the synapticula are also very irregular, and it has nothing like the regular continuous lamellæ shown in Reuss' figure (1866, pl. ii, fig. 3*b*). Specimens of *Astræopora* in the geological collection of Glasgow University have no synapticular platforms as regular as those in *Octotremacis*. Of the Indian Miocene species, *Astræopora hemispherica*, Dunc., there is unfortunately no information as to the structure of the synapticular platforms; but that species differs from *Octotremacis hochstetteri* by the greater number of septa, for according to Duncan it has six large and about six small septa. According to Bernard, however, in some recent species the horizontal platforms may be so regular "that the whole cœnenchyma appears to be composed of tiers of synapticular floors supported by columns passing through them". He says this structure is very variable and is especially well developed in *Astræopora expansa*, Brügg., and *A. horizontalis*, Bern. In the former he describes the cœnenchyma as consisting of nearly continuous horizontal floors (1896, p. 86).

Thanks to the kindness of F. J. Bell, Esq., I have had the opportunity of examining the types of these two species. *A. expansa* has a flat corallum, shaped like a wide incomplete funnel; at one part of the base a vertical section $\frac{3}{4}$ in. in thickness shows that the horizontal lamellæ are continuous and regular. The type-specimen of *A. horizontalis*, Bern., is a thin sheet, convex above and concave below. Unfortunately the edges are nearly perfect, so that they do not show the internal structure, and the fractures on the under surface do not give any clear evidence as to the nature of the horizontal lamellæ. As the type is the only specimen, it is thought unjustifiable to cut it in order to determine its structure.

If Bernard's view be correct, the horizontal lamellæ are of no diagnostic value, as they depend largely on the shape of the corallum, in flat coralla the vertical element being reduced and the horizontal platforms being well developed. The spreading growth of some coralla may, however, be the result rather than the cause of the predominance of the horizontal element. It does not seem possible to decide as to the value of this character until the internal structure of the recent species is better known. The most convenient course at present is therefore to retain *Octotremacis* provisionally as a sub-genus of *Astræopora* characterized mainly by the regular development of its synapticular platform.

Age.—*Octotremacis* was identified as Miocene because the other corals from Java described by Reuss were of that age. The type of this genus was, however, found under different conditions from the rest of the collection. It was a fragment collected from a trachyte breccia at Tjukang-Raon, and there is no direct evidence from Java as to its age. It may have been introduced into Miocene tuffs from an underlying platform of older rocks. The specimen from New Guinea was found with a series of corals and Foraminifera which indicate that it is Eocene and probably Middle Eocene (Gregory and Trench, 1916, p. 532). The type-specimen from Java is probably of the same age.

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IV.—On the Geology of the District from Cil-y-Coed to the St. Annes–Llanllyfni Ridge (Carnarvonshire).

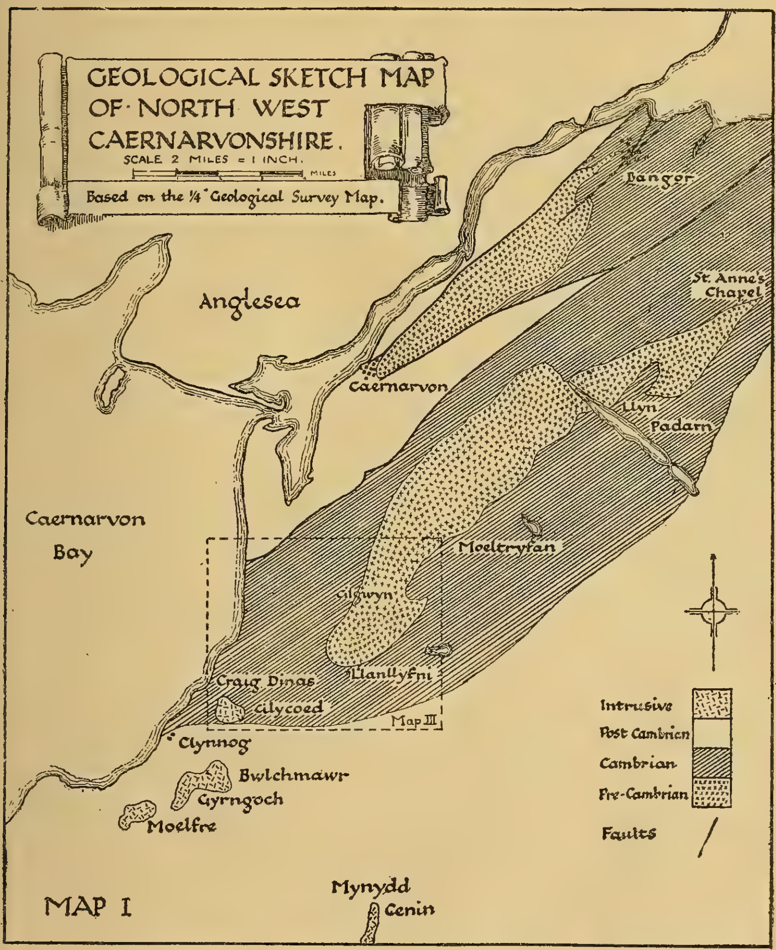
By E. WYNNE HUGHES, M.Sc., F.G.S.

(PLATES I and II and two Text Maps.)

Contents.

I. Introduction. (See Map I in text.)

THE existence of two ridges of Pre-Cambrian rocks in South-West Carnarvonshire is well known. The more northerly of these ridges extends from near Bangor to Carnarvon, a distance of just over 8 miles. It runs in a south-westerly direction, close to and parallel with the Menai Straits, and terminates at the hill called Twthill—a prominent feature in the town of Carnarvon. The more southerly ridge—commonly known as the St. Annes–Llanllyfni ridge—stretches from St. Annes in the Nant-Ffrancon Valley to the village of Llanllyfni in the Nantlle Valley. This ridge is 12 miles long and has a south-westerly trend; it is therefore roughly parallel to the Carnarvon–Bangor ridge, from which it is distant about 2 miles. It is with the area at the south-west end of the St. Annes–Llanllyfni ridge that the following remarks are concerned. The object of my



investigation has been to establish the succession of rocks in this area, and to correlate it, if possible, with the main portion of the ridge lying to the north-east. The results are set out in detail in the following pages. Text-map I shows the position of these two Pre-Cambrian ridges and also the extent of the area to be considered in detail.

II. Previous Literature.

Concerning the geology of these two ridges, the controversy as to the age of the rocks and their relation to the neighbouring formations has produced a voluminous literature. It is unnecessary to dwell in great detail upon this literature, and only the main conclusions, in as far as they appear to affect the area to be described, need be considered here.

1. General.

In 1866 the Geological Survey memoir of North Wales was published. From this it is seen that Ramsay maintained that the base of the Cambrian system in Carnarvonshire is not seen.[1] He further considered that the Cambrian Slates and Grits pass downwards into a conglomerate which in turn passes by insensible gradations into a quartz-porphyry which forms the core of the St. Annes–Llanllyfni ridge.[2] This gradual transition of the conglomerate into a quartz-porphyry was explained as a metamorphic change brought about by pressure, and the quartz-porphyry itself was supposed to be the extreme stage of the transition.[3]

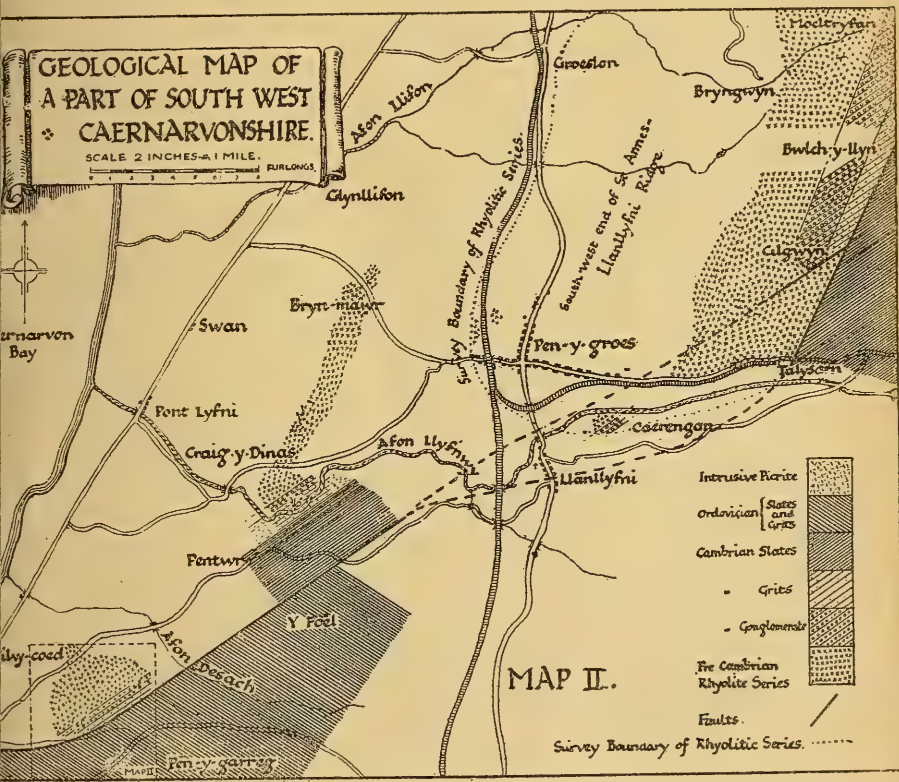
This somewhat interesting interpretation of the relation between the conglomerate and the quartz-porphyry resulted in an examination of the area by several geologists, amongst whose number were Blake, Bonney, Hicks, and McKenny Hughes, and at a later period Tawney and Geikie. All agreed that the theory of the metamorphic origin of the quartz-porphyry was erroneous, and that in reality the mass was composed of an original igneous rock. There was, however, considerable divergence of opinion as to whether the rocks were of intrusive or extrusive character. Hicks,[4] McKenny Hughes,[5] and Bonney[6] considered that this so-called quartz-porphyry was an eruptive mass composed of lavas, tuffs, and breccias, showing in places both fluxion and spherulitic structures. Tawney maintained that these rocks were intrusive.[7] Blake also at first maintained that they were intrusive, but later he modified this view and admitted the possibility that they were contemporaneous lava-flows.[8]

A further controversy arose as to the significance of the conglomerate lying upon this igneous series. It was demonstrated by Hicks,[9] McKenny Hughes,[10] and Bonney[11] that the pebbles in the conglomerate were mainly composed of fragments from the underlying volcanic rocks, and accordingly they concluded that a geological break existed here, and that the conglomerate marked the base of the Cambrian system in Carnarvonshire. The series was thus implied to be of Pre-Cambrian age. On the other hand, Tawney[12]

[1] A. C. Ramsay, *Geology of North Wales* (Mem. Geol. Surv.), vol. iii, p. 2, 1866.
[2] Op. cit., p. 142.
[3] Op. cit., p. 140.
[4] Q.J.G.S., vol. xxxiv, p. 132, 1878.
[5] Q.J.G.S., vol. xxxiv, p. 142, 1878.
[6] Q.J.G.S., vol. xxxv, p. 310, 1879.
[7] Geol. Mag., Vol. IX, p. 552, 1882.
[8] Q.J.G.S., vol. xliv, p. 282, 1888.
[9] Q.J.G.S., vol. xxxiv, p. 148, 1878.
[10] Q.J.G.S., vol. xxxiv, p. 142, 1878.
[11] Q.J.G.S., vol. xxxv, p. 311, 1879.
[12] Geol. Mag., Vol. X, p. 70, 1883.

and Geikie [1] maintained that the conglomerate merely marked a phase in the Cambrian succession, and agreed with Ramsay that the base of the Cambrian succession was not exposed in Carnarvonshire. Blake also had previously maintained this latter view,[2] but at a later date he went so far as to suggest that the Moel Tryfan conglomerate—lying directly on the volcanic series—was of post-Cambrian age.[3]

The view generally held nowadays is that although no unconformity has been shown to exist anywhere along the ridge, yet the volcanic series is Pre-Cambrian and the conglomerate is basal Cambrian.



2. Particular Area, including Cil-y-Coed, Craig-y-Dinas, and Bryn-mawr. (See Map II.)

Turning now to the literature relating to the district immediately south-west of the main ridge, one finds that very little attention has been paid to the ground. The Survey memoir of 1866 only refers to

[1] *Ancient Volcanoes of Great Britain*, vol. i, pp. 160, 163, 1897.
[2] Q.J.G.S., vol. xliv, p. 288, 1888.
[3] Geol. Assoc. Report of Blake's Caernarvonshire Excursion.

the area in a very general way. The village of Llanllyfni is mentioned as the most southerly extremity of the quartz-porphyry of the St. Annes–Llanllyfni ridge,[1] and the conglomerate is said to extend in this south-westerly direction no further than Mynydd Cilgwyn.[2] The exposures at Bryn-mawr, Cil-y-Coed, and Craig-y-Dinas are not referred to at all by name; but in the 1 in. Geological Survey map published in 1850 the area containing Bryn-mawr and Craig-y-Dinas is designated as *b′*—Lower Cambrian—and Cil-y-Coed is mapped as an intrusive felspathic rock. Hicks in a map accompanying his paper on the Pre-Cambrian rocks of Carnarvonshire indicated that he considered the rocks of Cil-y-Coed, as also of Pen-y-gaer, Tre-Ceiri, Yr Eifl, Gryn-ddu, Gryn Goch, Bwlch Mawr, and Mynydd Cenin, to be of Pre-Cambrian age.[3] The igneous rocks at all those localities, however, have been claimed by Harker as of Ordovician age.[4] Again, in a further paper, Hicks claimed that the rocks at Craig-y-Dinas were of Pre-Cambrian age,[5] and with regard to Cil-y-Coed he writes as follows:—

"In the absence of true Lower Cambrian rocks in this area, the evidence of their age has to be frequently based on the general character of the rocks themselves and the behaviour of the beds in contact with them . . . The small mass to the north of Clynogg Fawr (presumably Cil-y-Coed or Pen-y-garreg) is of the same character as the above-mentioned masses—a quartz-porphyry—and is also surrounded by Upper Cambrian rocks, and on one side by even Lower Cambrian beds also unaltered in contact." [6]

Tawney also visited this district, and in his paper on "The Rocks of Caernarvonshire", after a general discussion of the rock exposures in the county, he remarks:—

"It seems to me that there is sufficient evidence that these are igneous rocks intruded through Cambrian shales in the manner delineated in the Geological Survey Map. To begin with, the mass about 1 mile north-east of Clynnog, at Cil-y-Coed, is a quartz-porphyry of pinkish grey colour." [7]

Harker, in his Sedgwick Essay on "The Bala Volcanic Series of Carnarvonshire", refers to the mass at Cil-y-Coed in the following words:—

"Proceeding south-westerly we come to Clynnog district, where a number of distinct intrusions occur, which unfortunately have not all been studied in detail. There is a chain of four large hills due to four sets of connected intrusions. The other intrusions in the neighbourhood are quartz-porphyries of various characters, the Pen-y-gaer rock being a beautiful granophyre, while the little bosses of Cil-y-Coed, north-east of Clynnog-fawr and Moelfre near Llanhaelhaiarn, show Rhyolitic affinities." [8]

III. Exposures.

The country for some distance to the south-west of the St. Annes–Llanllyfni ridge is comparatively flat and low-lying. It is mainly

[1] Mem. Geol. Surv., 1886, p. 140.
[2] Op. cit., p. 143.
[3] Q.J.G.S., vol. xxxv, p. 297, 1879.
[4] Harker's *Bala Volcanic Series of Carnarvonshire*, 1888, p. 44.
[5] Q.J.G.S., vol. xxxv, p. 296, 1879.
[6] Op. cit., p. 298.
[7] Geol. Mag., Vol. IX, p. 552, 1882.
[8] *Bala Volcanic Series of Carnarvonshire*, 1888, pp. 44–5.

drift-covered, and in consequence well cultivated. As a result only three rock-exposures occur in this area—Cil-y-Coed, Craig-y-Dinas, and Caer Engan. Cil-y-Coed and Caer Engan are two small hills, whilst Craig-y-Dinas, with Pentwr to one side of it and Bryn-mawr to the other, are on the slopes of rising ground. It will be convenient to consider each of these exposures separately, commencing with Cil-y-Coed, which is the largest and also the most south-westerly of the three.

1. Cil-y-Coed. (See Map II.[1])

A. Surface Features.—This hill, situated about three-quarters of a mile from the village of Clynnog Fawr on the north-west coast of Carnarvonshire, attains an elevation of about 480 feet O.D., and stands out prominently from the drift plain which stretches for 6 or 7 miles along Carnarvon Bay. It is the first hill of a series increasing progressively in height towards the south, and it covers an area of nearly a quarter of a square mile, being about 1,000 yards long and 900 yards wide at its broadest part. The northern slopes of the hill are everywhere gentle, except at the extreme north-west, where crags are exposed, making the slope somewhat steeper. On the south-west and west sides, however, the ground drops very abruptly from 480 to 200 feet, below which level there is a gentle slope down into the plain. On the north side the rocks are smoothed by glaciation, and the lower flanks of the hill on every side are covered with a thin deposit of drift. The contour of the hill was undoubtedly carved out by the Irish Sea ice-sheet, which traversed the hill from the north. There is also a small capping of drift on the actual summit near the south-west extremity.

B. Pre-Cambrian, the Rhyolitic Series.—The hill in part undoubtedly owes its prominence to an igneous rock which is exposed more or less continuously in a line of crags on the west side extending from the roadway to the top of the hill, a distance of about 650 yards.

(i) *Stratigraphy* (see Map II).—It will be convenient to begin our description with the most northerly rocks exposed. These are to be seen on the north-west side of the hill, 20 yards away from the small quarry that is situated here. In hand specimens the rock appears to be a dark felsite, noticeable for the presence of numerous porphyritic crystals of quartz and of pink felspar. The groundmass is fine-grained and compact, hence the rock is very hard and tough.

The next exposure examined is in the quarry itself, where the rocks appear in hand specimens to be rather different from those just described. Although still felsitic-looking the rocks here are light-coloured, and only on close examination are any porphyritic crystals to be seen. In the mass the rock appears to be a rhyolite, and it is probably to the rock exposed in this quarry that Tawney and Harker refer. The rocks are much jointed and sheared, and readily break into angular chips. The main joints strike E. 10° N. and dip N. 10° W. at an angle varying from 60° to 80°. Other joints strike

[1] The area here dealt with is shown on Map II in dotted lines.

N. 40° E. and dip N. 50° W. at an angle of 60°, being thus roughly at right angles to the major joints.

In traversing the hill in a south-easterly direction from the quarry several rock exposures are met with. A few yards away from the quarry a dark rock, containing porphyritic crystals of quartz and pink felspar, is seen once more. It is in every respect macroscopically similar to the dark felsitic rock mentioned above. We thus have a band of pale felsitic rock (which we may term the pale variety) lying between two dark felsitic bands (which we may term the dark variety). The more southerly band is about 40 feet wide. Following is a narrow band of the pale variety. Succeeding this a dark felsitic rock again occurs as a band about 20 feet wide. Macroscopically it only differs from the dark bands in that the pink felspars are distinctly smaller. This band is succeeded by another of the pale variety—15 feet thick—and in turn by a massive dark band, macroscopically very similar.

Proceeding eastwards from this point, there is no exposure for fully 100 yards until another small quarry is reached. From here on to the most easterly part of the hill, igneous rock is exposed at several places, but in all cases it consists of the pale variety, macroscopically similar to bands already noticed in the first quarry.

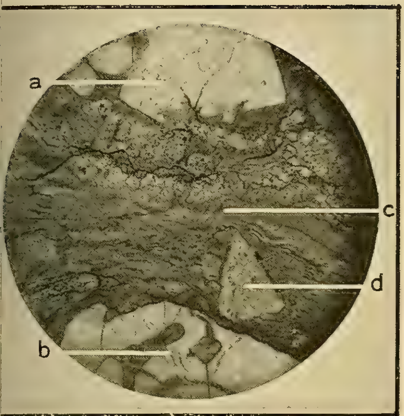
Along the south-west flanks of the hill a similar alternation of the pale and dark rocks is evident. These bands, however, are not persistent. For instance, the thin band does not occur on this side, so that two bands have here coalesced, giving a massive band of the dark variety having a width of fully 100 feet. Further south occurs also a tongue of the dark variety wedging into the pale variety. The line of strike given by this rough banding of the two varieties of rock is N. 60° E.

(ii) *Microscopic Description.*—On examining thin sections of the rock from the various exposures there is found to be a surprising resemblance between the pale and the dark varieties.

(*a*) Phenocrysts.—In both cases porphyritic quartz and felspar crystals are prominent, the quartz being the more abundant. The quartz sometimes show good crystal forms, but more often are corroded and rounded (Pl. I, Figs. 1, 2), and frequently the matrix may be seen in cracks in the crystals (Pl. I, Figs. 1 and 5). Most of the porphyritic crystals of felspar are plagioclases with multiple twinning (Pl. I, Fig. 5), but in nearly all cases simply twinned or untwinned crystals of orthoclase are also present (Pl. I, Fig. 1). The plagioclases appear to approximate to albite, and crystals of chequer albite[1] are occasionally present. This chequer albite is sometimes intergrown in perthitic fashion with untwinned felspar. Phenocrysts of biotite are also sparingly distributed throughout the rock. Muscovite, evidently of secondary origin, is always present.

(*b*) Groundmass.—These various phenocrysts are embedded in a felsitic groundmass. This again shows a general similarity in both the pale and the dark varieties, although a certain amount of

[1] J. S. Flett, Mem. Geol. Surv. (Newton Abbot), 1913, p. 60.



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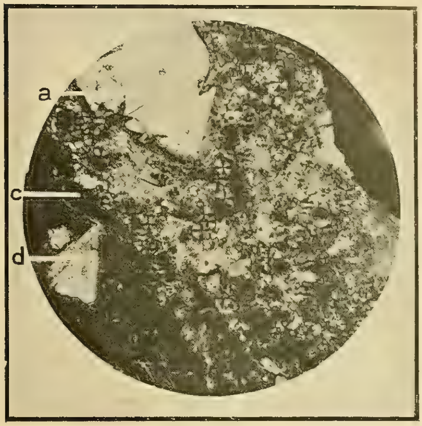

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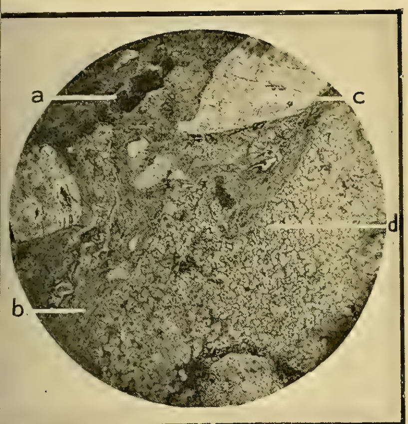

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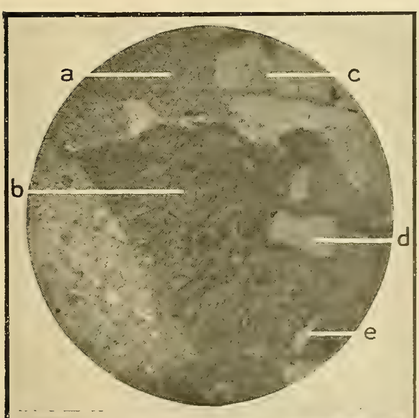

6

ROCK-SECTIONS, CIL-Y-COED.

variation is usually to be seen even in a single rock section. The matrix is typically cryptocrystalline, but occasionally becomes microcrystalline in character. Microspherulitic textures are of frequent occurrence, and on the whole this is more commonly the case in the dark variety.

In many cases the manner in which the various types of matrix are intermingled one with another and drawn out in streaky fashion shows that we are dealing with rhyolites having a well-defined flow-structure. This structure is sometimes developed on a very small scale (Pl. I, Figs. 1, 3). In other cases, however, the original character of the rock is by no means so clear, since in these the matrix with its different types of recrystallization presents a patchy rather than a streaky texture, suggesting at first sight a tuff. The streaky appearance, however, still persists to a certain extent, and in such cases the patches frequently end off rather abruptly along the direction of the flow-structure. It is extremely difficult to determine whether such rocks are lavas with flow brecciation or rhyolitic tuffs containing rhyolitic lapilli.

The presence of the very numerous and large felspar phenocrysts and still more so of the quartz phenocrysts immediately suggests that the rocks belong to a series of Pre-Cambrian age, since these characters appear to be of universal occurrence in the Pre-Cambrian rhyolites of Wales, whereas they are not found in the Ordovician rhyolites. In this connexion it is also noteworthy that the microspherulitic texture described above appears to be of frequent occurrence in the Pre-Cambrian rhyolites of North Wales, whereas it is not found to any extent in rhyolites of Ordovician age in North Wales.

C. Cambrian Sedimentary Series. (i) *Conglomerate.* (*a*) Stratigraphy.—Beyond the rhyolite we come to the crags which form the highest ridge on the hill at its south-west end. These crags are due to the presence of a hard conglomerate, the nature of which is well shown on the weathered surfaces. The well-rounded pebbles in this conglomerate vary considerably in size; whilst the majority are from 1 to 2 inches in diameter, others may attain a diameter of 12 inches. These pebbles are embedded in a fine gritty matrix. All the pebbles consist of felsites with porphyritic crystals of quartz and felspar, and they closely resemble the rocks of the rhyolitic series already described. In fact, near the line of junction of the conglomerate and the rhyolitic series, where the pebbles of the conglomerate have been pressed into the rhyolitic rock, the resemblance between the two is so close that it is only on careful examination that the outline of the pebbles can be seen.

This conglomerate strikes N. 80° E. When followed across the strike in a south-westerly direction the conglomerate passes into a grit which is, however, still occasionally pebbly. This conglomerate band continues until it is buried in the drift on the south-west slopes of the hill.

Proceeding along the strike in the opposite direction—north-east—the pebbles decrease rapidly in size in the course of a few yards, but the matrix retains its original character. In a newly opened quarry at the north-east end of the hill, quite a number of pebbles of rhyolite, some 3 to 4 inches long, are seen, but the majority of the pebbles are small and well rounded. It is only in this exposure that we get any indication of stratification in the conglomerate. Generally the dip of the rock is quite obscure, as is often the case in massive conglomerates; but in the freshly cut rock in this quarry alternate layers of pebbles and fine grit are distinctly visible. The lie of the pebbles suggests a dip of about 50° to S.E. In the quarry the rock is seen to be jointed, some joints sloping in the direction of the dip of the pebbles, crossed by others at right angles.

(*b*) Microscopic Examination.—Several thin sections were prepared from specimens collected from different places along the outcrop, both from the highly pebbly conglomeratic portion and from the less pebbly and more gritty portion. Every slide confirms the conglomeratic nature of the rock. They show the presence of felspar, quartz, and numerous chips of rhyolite and fragments of tuff (Pl. I, Fig. 6; Pl. II, Fig. 1). The felspars usually exhibit multiple twinning, but are mostly decomposed. The quartz almost invariably show subangular edges. The matrix is felspathic and fine-grained, often containing small crystals of muscovite.

Sections of some of the larger pebbles were also examined, and these compare in every respect with the rhyolitic rocks described above (p. 19). They contain crystals of felspar and quartz embedded in a felsitic groundmass, which in some cases shows a characteristic flow-structure.

At right angles to the strike—in a south-east direction—the conglomerate rapidly changes to a grit, the width of a distinctive conglomerate being about 18 feet.

(ii) *The Grit Band.*—(*a*) This band of grit is about 12 feet thick, and extends from the south-west to the north-east end of the hill. Under the microscope the grit is seen to contain angular and subangular crystals of quartz in large number, along with numerous felspar crystals (partly kaolinized); and occasional chips of rhyolite also occur (Pl. II, Fig. 1).

(*b*) This fine grit, when followed southwards across the strike, gives place to a distinctly coarser rock which is very much weathered. When followed along the strike to the south-west this rock becomes still coarser and still more weathered. A microscopic examination shows the rock to be largely composed of angular quartz crystals—often sheared—set in a felspathic cement (Pl. II, Fig. 5).

Both these bands of grit, fine and coarse, persist in a northeasterly direction for a distance of 900 yards, with but a slight break where the hill is capped with drift. At the north-east end of the hill there is the same succession of conglomerate, fine grit and coarse grit, precisely as one would expect to find them on the supposition that the dip is, as stated above, S. 30° E.

There is a decided dip in the ground beyond the outcrop of the quartz grit, and no further exposure is visible, all the land on the south-east side of the grit being under cultivation. This is most unfortunate, as it is impossible without further exposures on that side to determine the exact relation of the grits to the other formations of the district.

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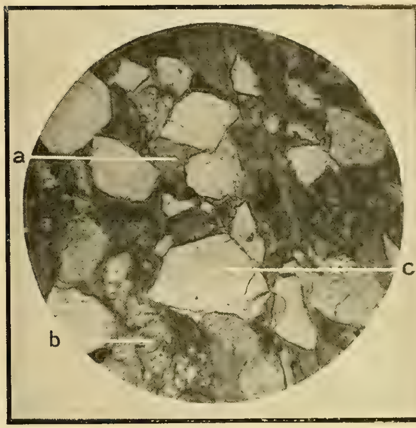

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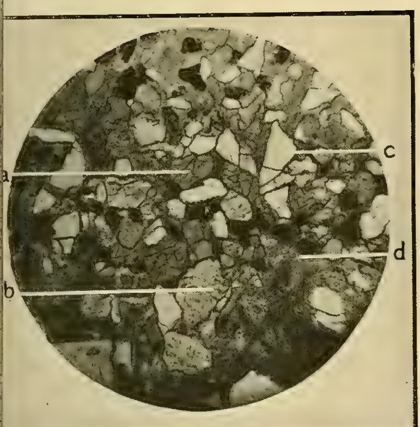

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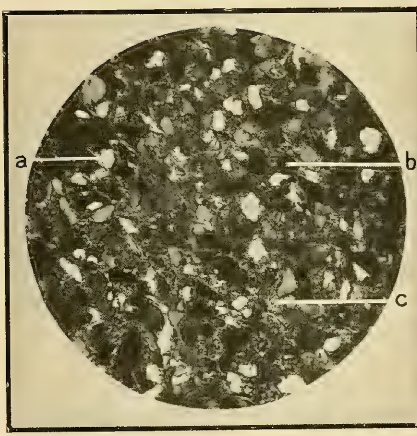

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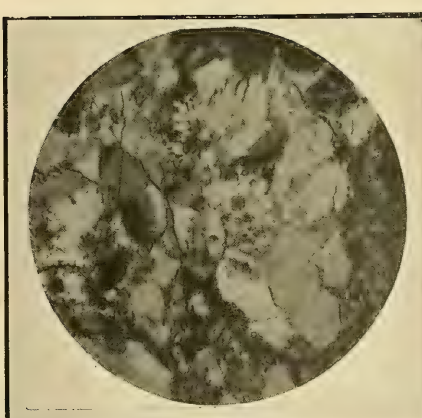

6

ROCK-SECTIONS, CIL-Y-COED; AND 4 AND 6 BWLCH-Y-LLYN.

D. Summary of the Succession.—We have then at Cil-y-Coed the following descending sequence:—

(i) A quartz grit 6 or more feet thick.
(ii) A fine felspathic grit 8 feet thick.
(iii) A conglomerate 18 feet thick.

All with a strike N. 60° E. and a dip of 50° to S. 30° E. These rocks rest on

(iv) A volcanic series consisting of rhyolitic lavas and tuffs which appear to dip 60–80° N. 10° W.

The pebbles in the conglomerate are undoubtedly derived from the underlying rhyolitic series.

This apparent discordance of dip suggests the presence of an unconformity between the sedimentary rocks and the volcanic series of rocks. The exposures, however, are not sufficient to actually prove the existence of this unconformity, and it would require considerable trenching to make it apparent.

E. Relation to the Surrounding Areas.—On attempting to trace the beds into surrounding areas we find that Cil-y-Coed is somewhat isolated.

(i) *North and West Side.*—On the north and west side the mass is flanked by glacial drift, which stretches as a continuous sheet right to the seashore, 500 yards distant.

(ii) *South-East and East Side.*—On the south-east and east side the ground is under cultivation, and no semblance of solid rock is to be seen except in a field near Garregboeth, distant 30 yards from the nearest exposure of the grits. Here an arenaceous slate is seen, but it is doubtful whether this rock is really in situ. Assuming that it really is in place, then it undoubtedly forms a continuation of a considerable mass of arenaceous slate which is exposed at Pen-y-garreg some yards further on. Between these two exposures there is an intrusive mass of picrite.

This band of arenaceous slate gives rise to a prominent feature at Pen-y-garreg, and it can be traced for at least two miles to the south-west, the outcrop generally running in a north-east to south-west direction.

In the Survey memoir this arenaceous slate is considered to be of Silurian (Ordovician) age, but no fossils have as yet been found in the neighbourhood. The slate is very different from the blue and purple slates of the Cambrian Series, which are so persistent in the Nantlle Valley and were traced by the Survey as far as Llwyd-Coed, three miles north-east of Cil-y-Coed. The Survey assume the existence of a fault in this neighbourhood throwing down the Silurian beds against Cambrian rocks. The memoir states:—

"South of Llanllyfni the strike of the Cambrian rocks changes to east and west, and the purple slate does not occur south or south-west of Mynydd Llanllyfni and Ty Coch near Clynnog Fawr. The drift-covered district further south is composed of black and ferruginous Silurian shales and grey sandstones. The point farthest south where purple slate has been found is at Llwyd-Coed about a mile south of Llanllyfni, and to the west of the last-named place the ground is so obscure that the reason for the disappearance of the slate is unknown. The fault which throws the (Cambrian) slate against the quartz porphyry ridge (St. Annes–Llanllyfni ridge) is probably continued along the boundary of the trap as far as Llanllyfni, and west of that village perhaps throws the slate down against the low Cambrian grits and conglomerates that form the western boundary of the porphyry."[1]

If we accept these slates on the south-east side of Cil-y-Coed as Ordovician, as the Survey imply, the only inference that can be drawn is that the Cil-y-Coed Series is of earlier date than Lower Ordovician.

(iii) *South-West Side.*—On the south-west side the rock surface slopes steeply until cultivated land is reached. This is the case all along this side except at the extreme end of the mass. Here the rock disappears in a wooded glen, and although the glen is narrow and deep, with a brook running down its entire length, no exposure is seen anywhere in the glen; but the debris in the bed of the brook suggests the proximity of the rhyolitic series. On the south side of this brook and 30 yards from it is an old "trial" level. This adit cuts into slate. The slate is black and is irregularly cleaved, the cleavage striking E. 10° N. and dipping 80° S. 10° E. In this adit there are about five hard black bands varying from 1½ inches to 2 feet in thickness and dipping in the same direction as the cleavage, but at a slightly smaller angle. The black bands are not cleaved, but are somewhat stratified parallel to their edges. They undoubtedly mark the true dip of the beds, which is therefore about 60° to the south. The slate in the adit is undoubtedly identical with the black ferruginous slate of the Ordovician system. It is in the direct line of strike of the grits on Cil-y-Coed.

The difference in the dip, but the much greater difference in the nature of the exposures on each side of the brook, coupled with the narrow glen separating the two, suggests the presence of a fault at this point. The map accompanying the Survey memoir shows a fault between the Cambrian and the Silurian Series curving round to the west at a point about 100 yards to the north-east of Cil-y-Coed. This fault has already been referred to (p. 21) in the extract from the Geological Survey memoir. A continuation of this fault in its south-westerly direction for another 1,200 yards, before turning to the west, would bring it down the glen separating the Cambrian and Pre-Cambrian rocks from these Ordovician slates in the quarry. Such a prolongation of the fault is shown in Maps I and II.

(iv) *North-East Side.*—Following the strike of the Cil-y-Coed rocks in a north-easterly direction we come again to cultivated land, where no rock exposure is visible. A careful search in all the fields on this side of the hill discloses no rock exposures. The River Desach cuts its way through a gap on this side, but even here no rock exposures are found. A little way on, however, at Pentwr, half a mile from the most easterly exposure on Cil-y-Coed, a small quarry was opened in 1912 for building-stone. The rock here exposed is a bluish fine-grained grit, approximating almost to a hard shale. At the south-west end of the quarry is green slate, but no indication of the dip is disclosed in this exposure. Further to the east, 60 to 70 yards away, there is again an exposure of green slate; the weathered surface shows the cleavage to strike E.N.E.–W.S.W.,

[1] Mem. Geol. Surv., 1866, p. 143.

but the dip of the beds is not clear in such a small exposure. Continuing from here in a N.N.E. direction we come to a much larger exposure of rocks at Craig-y-Dinas, separated from Pentwr by three small exposures of purple slate. The several exposures in this neighbourhood will now be described in greater detail.

2. Pentwr, Craig-y-Dinas, and Bryn-mawr.

These three places are on the slopes of a ridge which stretches practically from Glynllifon to Cil-y-Coed. The crest of this ridge along almost its whole length attains an altitude of 200 feet. At Craig-y-Dinas the River Llyfnwy cuts through the ridge in a roughly semicircular sweep exposing precipitous rocks at several localities on both banks of the river.

A. Cambrian, Sedimentary Rocks. (i) *Conglomerate.*—This rock is best exposed on the right bank of the river at the end of the gap farthest from the sea. The pebbles in this conglomerate are comparable in size with those at the north-east end of the exposures at Cil-y-Coed, being seldom more than an inch in length. They consist essentially of rhyolitic and felsitic chips. In addition occasional chips of a slaty nature occur, and in this respect the rock differs from the Cil-y-Coed conglomerate. The matrix of the conglomerate is felspathic, and approximates both in hand specimens and under the microscope to that already described at Cil-y-Coed. The rock is considerably sheared, and the pebbles have arranged themselves in the direction of shear, which dips generally at an angle of 70° S.S.E. The true dip of the conglomerate is obscured by cleavage.

(ii) *Grit.*—Overlooking the conglomerate, to the south-east of it, is a coarse grit in which there are several bands of a much finer grit. Some of these bands, though only 1 inch thick, are very persistent. In one locality the river runs for 100 yards in a N.E.–S.W. direction. Here the bands are perfectly horizontal, suggesting that the strike of the rock is approximately in the same line. Further down the river runs east and west, and here the dip of the beds can be observed owing to the alternation of fine and coarse bands. A lateral gap, at another locality further east, shows that the banding is persistent on both sides of the gap. The dip given by this banding is 50° S.E.

At the extreme southerly bend of the river the grit becomes much less felspathic, approximating more nearly to a quartzite. The rock weathers almost white, and on breaking shows crystals of opalescent quartz. This type of rock is predominant on the south-east bank of the river. Near the farm of Pen-y-bont (also on the left-hand side of the river) there is another exposure of quartz grit. It forms a small island bounded on one side by the river and on the other side by a "cut out" or old overflow channel. The line of outcrop here trends 20 N. of E., and the beds are very nearly vertical. This does not agree with the observations in the main mass.

(iii) *Purple Slate.*—For some distance beyond this grit the land is completely under cultivation and no exposures are visible. However, in a well that was dug in 1913 in the school playground at Bryn-eurau (500 yards south-west of Craig-y-Dinas) purple slate was reached. Exposures of purple slate also occur in the meadow below Coch-y-big, and also near the outhouses at Llech-y-dwr.

The dip of the slate cannot be ascertained, but the position of the three exposures gives some indication that the strike here is similar to that of the Cambrian slates in the Nantlle Valley—namely N.N.E.–S.S.W. If this were the case, purple slates would be present at a point within 300 yards of the grits at Craig-y-Dinas, in the exact position in which they should stratigraphically occur. Unfortunately the exposures are not sufficient to verify this. The Survey memoir mentions Llwyd-coed (2 miles to the north-east) as the most southerly exposure of the Cambrian purple slates.[1]

(iv) *Green Slate.*—One hundred yards due east of the exposure of purple slate at Llech-y-dwr the one already referred to at Pentwr is found. This exposure shows a band of fine grit in green slate, both macroscopically very similar to the grits and green slate that overlie the purple slate both in the Nantlle and Llanberis quarries. Still further east, 60 to 70 yards away, near Ysgubor-Wen, there is also an exposure of green slate. As already mentioned, the weathered surface shows the cleavage to strike E.N.E.–W.S.W., but the dip of the beds cannot be determined in such a small exposure.

No further exposures of any description are to be seen in this neighbourhood until we come to the hill of Y Foel. The whole of this hill consists of black slate showing poor cleavage and containing iron pyrites in large quantity. These slates are put down as of Ordovician age in the Geological Survey map, but no fossils have been obtained here. They closely resemble the black slates in the quarry to the south-west of Cil-y-Coed.

EXPLANATION OF PLATES.

Plate I.

Fig. 1.—Quartz-rhyolite, Cil-y-Coed. Showing two large crystals of corroded quartz (*a*) and (*b*); fluxion structure (*c*) winding round a crystal of muscovite on the left and of orthoclase (*d*) on the right. Natural light. × 18.

,, 2.—(Fig. 1 above, under crossed nicols.) Showing microspherulitic structure. The quartz crystal (*a*) and the orthoclase crystal (*d*) are the same as in Fig. 1. The flow-structure (*c*) is still evident. × 18.

,, 3.—Rhyolite, Cil-y-Coed. Showing very small spherulites (*d*) and fluxion structures (*b*); also porphyritic crystals of biotite (*a*) and orthoclase (*c*). Natural light. × 18.

,, 4.—(Fig. 3 under crossed nicols.) Showing microspherulitic structure (*a*) and (*b*). × 80.

,, 5.—Rhyolite, Cil-y-Coed. Showing slight flow-structure (*b*); phenocrysts of plagioclase (*a*) and quartz (*c*), corroded and invaded by the groundmass. Crossed nicols. × 18.

,, 6.—Conglomerate, Cil-y-Coed. Showing a chip of felsite (*a*); quartz (*d*); and an angular chip of tuff (*b*) containing a quartz crystal (*c*) and a decomposed felspar (*e*). Natural light. × 18.

Plate II.

,, 1.—Matrix of conglomerate, Cil-y-Coed. Containing subangular quartz crystals (*a*) and grains of felsite (*b*) and (*d*) in an abundant sericitic matrix (*c*). Natural light. × 18.

[1] See extract on p. 21.

FIG. 2.—Matrix of conglomerate, Cilgwyn. Containing subangular quartz crystals (*c*) and grains of felsite (*a*) in an abundant sericitic matrix (*b*). Natural light. × 18.

,, 3.—Quartz grit, Cil-y-Coed. Containing angular quartz crystals (*c*) embedded in a felspathic groundmass; small grains of felsite (rather decomposed) (*a*); occasional felspars (*b*); and abundant iron-ore (*d*). Natural light. × 18.

,, 4.—Quartz grit, Bwlch-y-llyn. Containing angular quartz crystals (*a*) embedded in an abundant matrix (*c*) now largely decomposed into sericite. Abundant iron-ore (*b*). Crossed nicols. × 18.

,, 5.—Sheared quartzite, Cil-y-Coed. Crossed nicols. × 18.

,, 6.—Sheared quartzite, Bwlch-y-llyn. Crossed nicols. × 18.

(*To be concluded in our next Number.*)

V.—Dr. Charles D. Walcott's Cambrian Geology and Palæontology.[1]

By V. C. Illing, F.G.S.

To the student of Cambrian geology, the writings of C. D. Walcott are always matters of enlightening study, not only for the matter they contain but also because they combine that admixture of stratigraphy and palæontology in which the latter, though accorded a prominent position, is always used to the full to subserve the wider claims of the former.

In a consideration of the series of papers on Cambrian Geology and Palæontology in the Smithsonian Miscellaneous Collections, the subjects covered are so varied and extensive that only a few of the more salient points can be considered. Perhaps it will be most convenient to discuss the material under the two general considerations of the more purely palæontological and the stratigraphical.

Among a series of new forms, some of the most remarkable are a number of Merostomata, Malacostraca, Holothuroidea, and Annelids, found in the Burgess shale of the Stephen Formation in British Columbia. In many cases the impressions of the organic structures are beautifully preserved in the fine-grained material, a fact to which full justice is done in the figures. The Merostomata are particularly interesting in this connexion as indicating to what a degree of development these Middle Cambrian faunas had attained. But to the stratigrapher it is the trilobites to which the main interest generally attaches, and among the various groups the Mesonacidæ or Olenellidæ stand out in their interest and importance. This family, characterized by its large head, large crescentic eyes, rudimentary facial sutures, genal spines, and long and variable thorax, has now been divided into a number of genera based mainly on variations in the thorax. Walcott recognizes six main stages in the development in an order of decreasing number of thoracic segments.

1. Nevadia Stage. The seventeen anterior thoracic segments are of the usual type, but are followed by eleven primitive posterior segments with spinous extensions.

2. Mesonacis Stage. The first fifteen segments are normal, except the third, which is enlarged, and the fifteenth, which has a median spine. The ten posterior segments are normal in shape but small.

[1] Smithsonian Miscellaneous Collections, 1910–15.

3. Elliptocephala Stage. The first fourteen segments are of the uniform type, while the posterior five segments are short and have long median spines.

4. Holmia Stage. The sixteen segments of the thorax are all of the uniform type.

5. Pædeumias Stage. The third segment is enlarged and the fifteenth segment is developed into a long spine. Beneath and behind this spine there are from two to six similar but smaller spines.

6. Olenellus Stage. There are only fourteen segments, of which the third is enlarged; the fifteenth segment has developed into a strong telson.

These changes in the thorax are sufficiently marked to form good generic delimitations in most families of trilobites, but it seems possible that the Mesonacidæ were undergoing rapid evolution; thus *Olenellus thompsoni* goes through a Holmia and Pædeumias stage before reaching the true Olenellus stage, and it may be that the discovery of new material will produce adults of transition stages, which will make generic identification difficult where genera have been made somewhat lavishly. It cannot be assumed that the collections of these Lower Cambrian forms are within measurable distance of completion.

A tentative sub-zoning of the Lower Cambrian is suggested by Walcott, based partly on the known stratigraphical occurrences of the Mesonacidæ in the few rare instances where successive forms exist in the same region, but mainly on the order of development.

D. *Olenellus* Zone (Upper).
C. *Callavia* Zone.
B. *Elliptocephala* Zone.
A. *Nevadia* Zone (Lower).

It will be interesting to find how far this tentative scheme will stand the test of future work. In Europe there are at present no positive facts by which the merits of the classification can be tested, but the series of beds of the Solva type of lithology, which occur in Wales and at Nuneaton in the English Midlands, are suggested as a hunting-ground—we cannot call it a "happy" one—which ought to be exhausted.

Another subject of general interest is the sudden appearance of life in the Cambrian period, which has for long engaged the attention of geologists, and acted as a harmless safety-valve when the impetus to theorize would not be denied. But in the case of the papers under discussion, behind the explanation there is a unique knowledge of the stratigraphical relationships of the Cambrian and pre-Cambrian rocks in North America, coupled with the new light shed on Cambrian stratigraphy by the recent researches of Mr. Bailey Willis and Mr. Blackwelder in China and of H.M. J. Deprat and H. Mansay in Yun-nan. The suggestion that there is an extensive break in the succession between the Cambrian and pre-Cambrian in all known localities, and that the Algonkian deposits are all epicontinental, appears to be the most probable explanation of the sudden appearance of prolific organic life in the Lower Cambrian. However, there must still remain the reservation that there is room for many important discoveries in the pre-Cambrian sediments; and although the contention may be true in the main, we may still find the progenitors of the Cambrian types in pre-Cambrian sediments situated in favourable localities, i.e. as distant as possible from the centre of the pre-Cambrian shield and beyond the limits of the Algonkian continents.

The present best-known pre-Cambrian fossils are the *Beltina* of the Belt series, but as an interesting supplement to the recent researches of Professor Garwood on the importance of the work of algæ in the formation of the geological record, Walcott describes a series of forms which he compares to the Cyanophyiceæ in the limestones of the Belt series and other Algonkian deposits of the Cordilleran region. Apart from these and a few rather doubtful cases, fossils are conspicuously absent in the pre-Cambrian. At the same time a break appears to exist between the pre-Cambrian and Cambrian in Asia, North America, and Europe. In Eastern Asia, as far as the evidence at our disposal will allow us to speculate, northward transgressive movements seem to occur in Lower and Middle Cambrian times, the transgression being continued into Upper Cambrian times. A similar set of movements are found in North America with minor oscillations and local regressions in Middle Cambrian times. In Europe there is a suggestion of similar conditions, a basal unconformity, a set of shallow water and laterally varying Lower and Middle Cambrian deposits with abundant non-sequences (some parts of the Middle Cambrian are more extensive and suggest open waters, but not deep waters), and an important transgression in the Upper Cambrian. Thus the Cambrian period in all three regions represents a time of great oscillatory transgressive movements culminating in the Upper Cambrian, during which the great Algonkian continents were invaded by shallow seas in which marine faunas thrived and multiplied.

The record of this oscillatory but generally progressive submergence is shown not only by the stratigraphical relationships of the strata, the proved disconformities and overlaps, but appears also in a general survey of the geological provinces of this period. Taking North America and Eastern Asia for example, the Lower Cambrian faunas can be broadly grouped into two main provinces, the North American with *Olenellus*, etc., and the Eastern Asiatic with its peculiar form *Redlichia*. In Middle Cambrian times there are again two broad subdivisions, the Pacific and Atlantic, but the dividing line has shifted eastward into the American continent, and the faunas are more varied as a result of the wider extent of shallow seas. During Upper Cambrian times there is a general merging of the various faunas, and the differentiation into provinces becomes indistinct. The history of the faunas is an indication of the history of their habitat, and this Cambrian record indicates the migration and then the breaking down of barriers, the gradual evolution of a narrow strip of shallow seas on the border of large continents, to an epoch of shallow seas and islands, and finally wide marine areas merging and growing around much diminished continental areas.

NOTICES OF MEMOIRS.

I.—Report of the Committee for investigating the Lower Carboniferous Flora at Gullane.[1]

Consisting of Dr. R. Kidston (Chairman), Dr. W. T. Gordon (Secretary), Dr. J. S. Flett, Professor E. J. Garwood, Dr. J. Horne, and Dr. B. N. Peach.

A NEW discovery of petrified plant-remains was made, in 1914, at a point below high-water mark near Gullane, Haddingtonshire. The place could only be reached at certain states of the tide. In order to accelerate collecting, blasting operations were proposed, and a grant voted at last meeting of the Association to meet the expenses. The locality, however, lies within the area of the Forth Estuary, and, although the military and police authorities readily gave permission to blast on the foreshore, it was considered inadvisable to act on that permission meanwhile. No part of the grant was used therefore, but sufficient material has been collected to amplify considerably the data already obtained. Some 150 thin sections of the material have been prepared and examined.

The flora represented in these sections is as follows:—

Lepidodendron veltheimianum, Sternb.
Stigmaria ficoides, Sternb.
Botryopteris (?) *antiqua*, Kidston.
Bensonites fusiformis, R. Scott.
Pitys primæva, Witham.
Pitys dayii, sp. nov.
Pitys, sp. nov.

Chief importance is attached to the specimens of *Pitys*, as so many well-preserved specimens have never been obtained elsewhere. Many of these examples had the bark preserved, while one of them consisted of a branch tip still clothed with needle-like leaves. Much light has been thrown on the stem structure of the genus, while the details of the connexion of leaf and stem have also been determined.

As regards the other plant types represented, it is interesting to note the similarity between the whole assemblage and the flora of the Pettycur Limestone at Pettycur, Fife. Indeed, the form *Bensonites fusiformis*, R. Scott, has not, so far, been recorded except from Pettycur. Both Gullane and Pettycur lie on the Forth, and the geological horizon of the rocks at both localities is not very different, so that the similarity of the floras is not surprising.

The specimens from Gullane occur in a greyish-white clastic rock, which on examination proved to be a highly decomposed volcanic ash. It is suggested that the decomposition of the ash, by vapours emitted from the volcano during its activity, produced solutions of mineral matter which caused the petrifaction of plant fragments included in the ash. These plant fragments occur quite sporadically through the rock, and they have evidently not been drifted in water. The petrifying solutions have been both calcareous and siliceous, so that some specimens are preserved in carbonate of lime, others in silica, while a few are partly in the one and partly in the other.

The perfection of the preservation is very striking, and it is proposed to continue collecting specimens when possible.

[1] Read before the British Association, Section C (Geology), Newcastle, 1916.

II.—The Palæoliths of Farnham.[1] By Henry Bury, F.G.S.

THE information contained in a previous paper on the same subject (Proc. Geol. Assoc., vol. xxiv, pp. 178–201) is here revised and enlarged. The implements of the Alice Holt Plateau (including Terrace A) are usually large (5 to 8 inches long), and very few are later than the Chellean period. On Terrace B, on the contrary, the majority of unabraded implements are small (3 to 4 inches long), and quite 40 per cent are Acheulean. There are also many flakes, used as scrapers, which may be Mousterian. Terrace C, beyond a few Le Moustier flakes, yields no clear evidence of its age; but it is not impossible that the valley may have been excavated to this depth in early Chellean times. On Terrace D unabraded implements are extremely rare, but among them are a few which may be of Le Moustier age. Another terrace (E) about 20 feet above the river is covered with a thick layer of drift, but has so far only yielded one implement.

REVIEWS.

I.—*Apractocleidus teretepes*: a New Oxfordian Plesiosaur in the Hunterian Museum, Glasgow University. By W. R. Smellie, M.A., B.Sc. Trans. Roy. Soc. Edin., vol. li, pt. iii, 1916.

IN this paper the author gives a very detailed account of the remains of a Plesiosaur collected by Mr. A. N. Leeds in the Oxford Clay of Peterborough. The skull and caudal region are missing, but otherwise the skeleton is nearly complete. In many respects this form is intermediate between *Cryptocleidus* and *Tricleidus*. Thus, in the fore-paddle the humerus articulates distally with the radius, ulna, pisiform, and a small accessory ossicle, as is the case in *Tricleidus*. On the other hand, in the shoulder-girdle the inter-clavicle is very small or absent, and the triangular clavicles meet extensively in the middle line as in *Cryptocleidus*. For these and other reasons the author has established a new genus for the reception of this form. Many of the characters, however, which are regarded as indicating the higher organization of this type, are certainly merely the result of the great extension of the ossification of the bones consequent upon the advanced age of the individual. Such characters are the extension forward of the scapulæ in advance of the clavicles, and the elongation of the dorsal rami of the scapulæ and of the postero-lateral processes of the coracoids.

This interesting paper is illustrated by nine text-figures and one plate.

[1] Read before the Geologists' Association, December 3, 1916.

II.—The Geology of Ben Nevis and Glen Coe (Explanation of Sheet 53). Memoirs of the Geological Survey, Scotland. By E. B. Bailey, M.A., and H. B. Maufe, M.A.; with contributions by C. T. Clough, J. S. Grant Wilson, G. W. Grabham, M.A., H. Kynaston, B.A., and W. B. Wright, B.A. pp. 247, with 12 plates. 1916. Price 7*s.* 6*d.*

THIS memoir describes the geology of the region that contains the highest mountain and perhaps the wildest and most rugged country in Great Britain. All phases of its geology are replete with interest.

The area is a greatly dissected part of the main Highland plateau, with a summit level of about 3,000 feet. Ben Nevis and other high peaks rising above this level are regarded as features dating from an earlier geographical cycle. Loch Linnhe, lying in a north-easterly direction along the shatter-belt of the Great Glen, divides the area into two unequal parts. Another system of valleys runs W.N.W.-E.S.E.; and these remarkable 'through' valleys, cut athwart the grain of the country, are consequent upon the pre-glacial uplift of the Highland plateau. Glacial erosion is believed to have cut off spurs and thus widened the valleys. In some cases it is responsible for hanging valleys, although general deepening of valleys by ice action is considered improbable. A large part in breaking up the 'through' valleys into segments is attributed to the formation of pre-glacial delta-watersheds or corroms. While accepting many of Professor J. W. Gregory's views as to the origin of fiords, the authors are not inclined to attribute so much potency as he does to earth-movements (gaping faults and joints) in the development of the typical West Highland fiords.

The subject of prime interest in this memoir, however, is the structure and succession of the Highland Schists. These rocks form the basement of the whole district, but are partly covered by extensive outpourings of Old Red Sandstone lavas (Glen Coe and Ben Nevis), and are intruded by great masses of plutonic rocks, principally granite (Ben Cruachan, Ballachulish, Ben Nevis). The Highland rocks consist of alternations of phyllite, mica-schist, and quartzite, with thin horizons of limestone which form good datum-lines for the interpretation of the structure. The folding of the rocks is very complex. Mr. E. B. Bailey has developed the view that the rocks are arranged in a number of great recumbent folds, which are frequently ruptured along fold-faults or slides. In certain cases the major folds have been bent into later secondary folds, and have been dislocated by ordinary faults. In consequence of the extraordinary inversion and repetition the beds have suffered, the original stratigraphical sequence is doubtful, and it is not known which is the top or bottom of the list of formations. As usual, in the interpretation of regions of extreme complexity such as this, differences of opinion arise; and in regard to the Kinlochleven district Mr. Carruthers holds views at variance with those of Mr. Bailey. The chief difficulty appears to be the number of formations recognized by the respective observers. Mr. Carruthers increases the number of stratigraphical horizons and consequently diminishes the complexity of structure. Without special knowledge of the area it is impossible to decide between the rival views. Mr. Bailey, however, accepts Mr. Carruthers' interpretation as on an equal footing with his own for the district in question, his own view being based on a restricted sequence and greater structural complexity.

The interest of the region is well maintained in the next series of rocks, the Old Red Sandstone lavas which centre about Glen Coe and Ben Nevis. They consist of hornblende-, pyroxene-, and biotite-andesites, with rhyolites, and have been poured out on to a very uneven surface of the Highland schists. The two great areas of lava in this region, although forming the highest ground, owe their preservation to subsidence within great circular faults. One of these encircles the Glen Coe lavas, except on the south, where the fault-line is broken through by the Cruachan granite. Igneous material rose along the peripheral fault during subsidence, but never penetrated to the inner side of the fault plane. The fault intrusion is chilled against the fault plane, and is usually separated from it by a band of flinty crush-rock produced by the friction of the subsiding mass.

Both the larger granite masses of the region show distinct inner and outer portions, of which the former are the younger. They are interpreted as magmas which filled the voids caused by successive cauldron-subsidences. The concentric arrangement of the Ben Nevis granites and lavas is explained in this way. The magmas are believed to have been emplaced largely by the stoping method described by Daly.

The detailed petrography of the Old Red Sandstone igneous rocks is dealt with in a separate chapter. Their composition is illustrated by a fine series of new chemical analyses. There is a useful historical account of the terms granite, granitite, tonalite, adamellite, banatite, granodiorite, etc., but the conclusions adopted as to their scope are open to criticism. Two new rock names, *aplogranite* and *appinite*, have been invented, but their definitions are at once too vague and broad to be of much use. The uselessness of measuring the quantitative relations of the minerals of igneous rocks by the recognized micrometric methods is illustrated by a highly fallacious diagram.

The various granites of the region have produced remarkable metamorphic effects on a great variety of rocks, including schists, sediments, and igneous rocks. These are dealt with in a chapter which is a distinct contribution to the literature of contact metamorphism.

A group of W.N.W. dykes of dolerite, basalt, and monchiquite are regarded as of Tertiary age. A small explosion vent in the Allt Coire na Bá may also be Tertiary. The breccia is invaded by a basic rock which proves to be a fresh nepheline-basalt.

The final chapters deal with the glacial phenomena and with the economic products of the area. Roofing slates and granite are quarried on a comparatively large scale at Ballachulish.

The memoir, which has been edited and mainly written by Lieut. E. B. Bailey, is excellently illustrated by twelve fine plates and numerous maps and diagrams. The Scottish Survey geologists are to be congratulated on the memorable results of a long, patient, and intricate piece of work.

G. W. T.

III.—Late Pleistocene Oscillations of Sea-level in the Ottawa Valley. By W. A. Johnston. Geological Survey of Canada, Museum Bulletin No. 24; 1916.

Although the attention of British geologists is at the present time mainly directed to economic problems, it is nevertheless very desirable that a paper of such scientific importance as that about to be discussed should be brought to their notice. The author has made a notable contribution to the study of late-glacial changes of sea-level, and the facts he has put on record might almost be said to constitute a complete demonstration of the applicability of the theory of isostasy to these changes.

It will be recalled that this theory ascribes the raised or tilted shorelines which are found around the centres of glacial dispersal to the sinking in of the earth's crust beneath the pressure of the ice-sheets, and its subsequent recovery when the ice has melted away. The depression and recovery were greatest at the centres of dispersal where the ice was thickest, with the consequence that the shorelines are highest near these centres and descend gradually towards the margins of the glaciated districts. Before they reach these margins, however, they invariably pass beneath the present sea-level. There are no late-glacial raised beaches in the peripheral parts of the glaciated districts, the shorelines which were formed during the retreat of the ice from these areas being all beneath the present sea-level. This relation indicates very clearly that the general sea-level must have been considerably lower during the earlier stages of retreat than at the present day, and the same conclusion can be arrived at on *a priori* grounds by considering the effect on the ocean-level of the binding up of enormous quantities of water in the ice-sheets.

We have, therefore, in seeking for an explanation of the late-glacial changes in the relative level of land and sea, two factors to deal with. The first is the isostatic recovery of the earth's crust, the second is the general raising of level of the ocean due to the melting of the ice-sheets. According as the first or second of these factors predominated there occurred either emergence or submergence in the isostatically affected areas.

This appears to be the explanation of the curious fact established by Brögger in the Christiania region, that the first change of level after the retreat of the ice was one of submergence, which, at a somewhat later stage of retreat, gave place to emergence. That this is the course of events to be expected from the interplay of the two factors mentioned is apparent from the following considerations.

1. At the period of deposition of the earlier late-glacial marine deposits from which Brögger drew his conclusions, about one-third to one-half of the total retreat of the ice-margin had been accomplished; and it is roughly at this stage of retreat, when the climate had already considerably ameliorated, and there was at the same time

a large body of ice still in existence, that the most rapid return of water to the ocean is to be expected.

2. Brögger has clearly established that the isostatic recovery progressed with a wave-like motion from south to north along the Cattegat, following up the retreating ice-margin. This seems to indicate that the recovery takes some time to get under way, and does not attain its maximum rate until the neighbourhood is altogether clear of ice.

At this particular period of the retreat, therefore, it would be natural to expect that the rise of the ocean level might be, for a time, faster than the isostatic recovery, and submergence would result. Later, when the isostatic recovery had gathered pace and the amount of water returning to the ocean from the waning ice-sheets had become gradually less, we might expect the isostatic recovery to attain the upper hand and give us progressive emergence.

Now the best test of the validity of this theory is its applicability to the isostatically affected areas of the British Isles and North America. Unfortunately, in the British Isles the highest late-glacial shoreline is only 100 feet above the present sea-level, and within this small vertical range evidence of the kind utilized by Brögger is not to be expected. In North America, until the appearance of the paper under review, no investigation, such as would bring to light a relation of this nature, appears to have been placed on record. Johnston now brings forward evidence, of a nature similar to that adduced by Brögger, to show that the late-glacial changes of sea-level in the Ottawa Valley were precisely the same as those established for the Christiania region, namely, that the sea first rose on the land as the glaciers retreated, and that it was not until a later date that emergence supervened. Moreover, he makes a further point of great importance in establishing the isostatic theory on a firm basis. This point, for which there was no direct evidence in the Norwegian case, is to the effect that the tilting of the Great Lakes region was in progress before and during the rise of the sea in the Ottawa Valley, for, presumably from a consideration of contemporaneous ice-margins, it is concluded that "the Ottawa Valley must have been, in part at least, occupied by the ice-sheet during the existence of Lakes Iroquois and Algonquin, and at least a small amount of uplift affected the region at the foot of Lake Ontario during the life of Lake Iroquois. Uplift also affected the northern portion of the Great Lakes region, and probably included the upper portion of the Ottawa Valley near Mattawa during the existence of Lake Algonquin, and while the ice-sheet still occupied the upper portion of the Ottawa Valley". Further, it is not a case of alternating elevation and depression, "for the results of investigations by numerous geologists, of the raised beaches of the Great Lakes region, has shown that differential uplift took place almost continuously as the ice withdrew."

We thus have direct proof that a district which was rising relatively to those around it was nevertheless undergoing submergence beneath the level of the sea, that in fact the two factors invoked to explain the late-glacial changes of level were in action simultaneously in the same region.

There is now but one thing wanting to make the analogy between the isostatic phenomena of America and Europe perfect in every detail, and that is the discovery of a shoreline corresponding to the 'early Neolithic' or 'Littorina-Tapes' raised beaches of Great Britain and Scandinavia. This should represent in the south a distinct resubmergence, and in the north a pronounced check or slowing down in the general emergence.

We must congratulate the author of the paper under review on having made a striking advance in Quaternary geology. Is it too much to hope that he will carry his researches further, and complete the history of the changes of level in his district down to the present day?

W. B. Wright.

IV.—Thirty-sixth Annual Report of the Director of the United States Geological Survey to the Secretary of the Interior for the year ended June 30, 1915. pp. 186, with 2 coloured plates. Washington, Government Printing Office, 1915.

By its very reticence and conciseness this slender volume is eloquent testimony to the extensive and multifarious character of the work carried on by the United States Geological Survey. How large and useful are the services it renders may be gathered from the following extract from the opening page of the report itself: "The recognition by citizens generally that the Geological Survey is a bureau of information as well as a field service has gradually placed upon it a large burden of work as well as of responsibility. The amount of correspondence involved in performing this public duty may be indicated by the fact that approximately 50,000 letters of inquiry were handled in the different scientific branches of the Survey last year. The scope of these inquiries is not less noteworthy, for they range from requests for information concerning the geology of every part of the United States or the water supply, both underground and surface, of as widely separated regions as Alaska and Florida, or for engineering data on areas in every state in the Union, to enquiries regarding the natural resources of foreign countries, especially those of Central and South America." So large has the Survey grown that for convenience of administration it is divided into six main branches, each of which is subdivided into various divisions, certain of which are further subdivided into sections. First and possibly foremost of them comes the Geologic Branch, which is responsible for the geological work of the Survey. Though it was primarily formed for the comparatively restricted task of the classification and examination of the public lands reserved to the state, its scope has been extended to the preparation of a geological map of the whole of the United States. The nature of its duties is best set forth in the words of the Report: "At present the geologic branch is not only the effective agency of the Survey in the geologic investigations carried on by the Government in all parts of the United States and Alaska but also the great geologic information bureau to which the American public, from Key West to Point Barrow and from San

Diego to Eastport, applies for knowledge of every sort concerning the earth's crust and its mineral constituents. To the people of this country and, in a surprising degree, to the citizens of other countries, the Survey is the principal source of geologic information regarding not only the geology of the United States and its possessions but also that of Mexico, Central America, and even South America. Through its correspondence it is asked for data regarding the geology and mineral deposits of all parts of the world. The geologic branch has therefore the double task of geologic surveying, including the investigation, description, and mapping of the geology and mineral deposits of all parts of the country, the classification of the public lands, and the publication of the results of its work on the one hand, and of furnishing to the public miscellaneous geologic information derived from all sources on the other." The Geologic Branch is divided into four divisions, viz. geology, Alaskan mineral resources, mineral resources, chemical and physical researches, which though working on independent lines yet co-operate effectively with one another. We read that the scientific staff of the division of geology at the beginning of the year consisted of 66 geologists, 33 associate geologists, 26 assistant geologists, 15 junior geologists, and 22 geologic aids, a total of 162. It must further be remembered that besides the Federal Survey many, if not all, the States have their own Bureaus of Mines and Geological Surveys, and much of the field-investigation and palæontological research has been conducted in connexion with the local staffs. In order to secure uniformity in the geological names the question is considered by a standing committee of the branch, the secretary of which scrutinizes the nomenclature and classification in all manuscripts submitted for publication. The work of the division of chemical and physical research is not wholly confined to the customary routine analyses, but includes many investigations of considerable scientific interest. The division of mineral resources is responsible for that valuable annual return entitled "Mineral Resources of the United States"; upon its preparation no fewer than sixty persons are wholly or partly engaged.

The Topographic Branch is engaged on geodetic work, and up to date has mapped 40·2 per cent of the entire country; its skilled staff numbers 159. One of the most important objects of the work carried on by the Water Resources Branch is the investigation of underground water with the view of the irrigation of arid areas; the skilled staff numbers 76.

The fourth Branch, viz. the Land Classification Board, which was the origin of the Survey, collates the results of the investigation of public lands made by the branches already mentioned. Since the classifications required by the public lands laws fall into two broad groups, depending upon the presence or absence of mineral deposits or of water respectively, the Board is divided into two divisions, the one for mineral and the other for hydrographic classification. Last of all we have the Publication and Administration Branches. The total expenditure on the whole Survey amounts to nearly one and a half million dollars.

This is not the place to discuss at length the points suggested by this Report or the lessons for ourselves that may be drawn from it, and we shall confine ourselves to a brief paragraph. There is much to be said for establishing an institution to serve a similar purpose for the British Empire—an institution which should ever be ready to explore outlying and little-known quarters of the Empire, and to investigate and report upon their resources,[1] and which should cordially co-operate with and encourage the local geological surveys. Something has already been done, and perhaps as the result of these tragic days something more may eventuate; we have at least been thoroughly taught the danger of depending solely upon the result of haphazard individual effort. At the Imperial Institute there is a small staff under the Colonial Office to undertake investigations of the kind in point, with particular reference to the Crown Colonies. Very useful work has been turned out, but all on too small a scale: the staff is not large enough, and the financial equipment far from generous or sufficient. Geological surveys exist at home and in the great dependencies: all work independently and without mutual co-operation. In Great Britain the Geological Survey, which—perhaps humorously—is placed under the Board of Education, has devoted itself to investigations of some scientific interest, but appears to have carefully avoided the risk of being reproached with doing anything which might prove of economic value. Only under the stress of war has it so far broken through its traditional aloofness from mundane affairs as to issue a series of monographs on the mineral resources of the United Kingdom. A small and distinct Survey is maintained in Dublin. To complete the picture of heterogeneity it only remains to add that the actual working of mines comes within the purview of the Home Office.

V.—Petroleum and Natural Gas Resources of Canada. By Frederick G. Clapp and others. Vols. I and II. Canada, Dept. of Mines, Mines Branch No. 291.

That the various members of the British Empire are alive to the extreme importance of the question of liquid and gaseous fuel is shown by the recent activities of the government departments of the chief self-governing Colonies in investigating their natural resources of oil and gas. Canada, whose oil industry dates back as far as 1857 and whose gas industry has now far outstripped the former in value, and is growing enormously, has rendered a service to the oil investigator in the publication of two volumes on Petroleum and Natural Gas Resources of Canada, which, in addition to a series of general chapters on Petroleum problems, combine in a very accessible form the available knowledge on the various fields, and include a series of useful maps.

The first of the volumes deals with general oil and gas problems, geological, chemical, engineering, and economic, and the composite authorship gives it this advantage, that the various subjects have each been considered by investigators and workers in the particular branch; thus we are spared the anomaly of the geologist writing on engineering or the engineer writing on geology, with the usual unfortunate results. It would have been preferable to include more of the Canadian element in the authorship, for certainly in the first volume the writers appear only at their ease when citing examples from the United States, but as a general treatise on petroleum vol. i will probably find a much wider circle of readers than those interested in Canadian oil-fields. In it are collected what is really a series of essays on petroleum problems, some of them but mediocre, a dull restatement of well-trodden ground, but others distinctly fresh and well-balanced, with clear concise wording where descriptive, and full of suggestive ideas where theoretical. It would probably have been of advantage to omit most of the first chapter, for to summarize the world's oil occurrences in thirty pages, country by country, is to attempt the impossible and to involve the bewildered student in a labyrinth of dead place-names.

Chapter ii contains much useful physical and chemical data, while under the heading "Geological Occurrence of Petroleum and Natural Gas", chapter iv, there is a clear and short account of the various theories of the production of natural hydrocarbons, in which the author safely joins both sides of the warring camps of the upholders of organic origin. But the remarks on oil migration do not break any fresh ground, and here unfortunately the need is most lamentable. There comes a time in the history of all theories when a few adverse storms are necessary to unsettle the fallacies which take root so easily and to orient ideas to fresh facts. It is a pity that the current ideas of oil migration have lived so long in the belt of calms, for, strange as it may seem when considering the importance of the subject, we do not yet know how, when, why, or how far an oil will migrate. Gravitation, capillarity, different specific gravity of water and oil (and some authors concede gas pressure) are the sum-total of the admitted agents on migration, yet it is doubtful whether any one of these has any primary effect on the initial movements of the oil, and it is just these which are so important. Gravitation in the accepted sense of the migration theorist requires free pore-space for downward motion, but water-borne sediments will certainly be water-clogged in their finer deposits. Capillarity will cause oil to migrate in fine dry deposits, but it is a movement from the larger pore-space to the smaller, not from the fine deposit to the coarse, and in addition there is the same difficulty that the sediments will almost certainly not be dry. The differential specific gravity of water and oil will have its expected result in the proper conditions, i.e. where the pore-space is large enough to allow a certain limited circulation of liquids, but the hydrocarbons originate in the fine-grained deposits, and it is just this initial migration from the fine deposits to the contiguous coarse deposits wherein lies the difficulties with the present theoretical ideas. When, however, the secondary processes which take place in argillaceous sediments immediately after deposition are examined, and the gradual diminution of pore-space during compacting, with its necessary out-pressing of water and other liquids, is taken into account, it is evident that here is a very potent factor in the expulsion of liquids from fine material which is easily compacted to coarse material which is more resistant to pressure. There is no doubt that the effect of earth stresses, as apart from the pressure of the overburden, will have similar results.

Turning now to the chapter on drilling, the 103 pages devoted to this subject are an extremely useful summary of the methods of drilling, dealing with the matter in a way which adds interest to a subject which is usually not very entertaining. The conservation of oil and gas resources is another subject of striking importance.

Vol. ii contains a description of the oil-fields of Eastern and Western Canada. In Eastern Canada the more important points of interest are the recently developed gas-field of New Brunswick, and the possible resources in oil shales in the same province. Ontario is still the chief oil and gas producer, but of recent years Alberta has been coming to the fore with a rapid increase in gas production. In this province the hydrocarbons are obtained from the Cretaceous Sandstone, at an horizon approximating to the Dakota sandstone. In Athabaska and contiguous regions there are the extensive outcrops of asphaltic sands, the so-called "Tar Sands", while farther north in the Mackenzie River region wide untapped areas are awaiting further development.

V. C. I.

VI.—Principles of Oil and Gas Production. By Roswell H. Johnson and L. G. Huntley. pp. 371. John Wiley & Sons. Price 16*s*. net.

THE geological aspect of the occurrence of petroleum and natural gas is by no means overburdened with explanatory textbooks, and although the volume under discussion deals in addition with other branches of the oil industry, a large proportion of its pages is devoted to geological considerations. To the European student it is also welcome inasmuch as it emphasizes the essentially American aspect of the subject, but the widespread occurrence of natural hydrocarbons in the American Palæozoic leads the authors into dangerous generalizations. Thus it produces the assertion that "it is probable that a considerable production will some day be developed in the older formations when they have been thoroughly prospected in Europe and Asia"; but it must be remembered that the conditions of occurrence of the Palæozoic rocks in the Central United States have not their counterpart on this side of the Atlantic, although Asia may produce many similarities. On the other hand, the long chapter on the Oil and Gas Fields of North America is distinctly good, and the chapters dealing with Oil and Gas Reservoirs and the Migration and Accumulation of Oil and Gas, although necessarily short, contain the germs of very suggestive ideas.

It is a distinct relief to get away from that obsession for anticlines which has of recent years somewhat obscured the vision of many oil-field geologists. To such an extent has this hypothesis been taken, that on several oil-fields the converse process of reasoning has been adopted and the presence of the oil been regarded as sufficient proof of the occurrence of the anticline. It is by no means suggested that the anticlinal occurrence of oil and gas is not of great importance, but the promulgation of the idea of its exclusive importance is to be deprecated, while the beautifully simple diagrammatic representation of the successive occurrence of water, oil, and gas in the arched strata is at its best but a crude and partial statement of the whole story.

The tendency of modern investigation has been to prove that the original nidus of the hydrocarbons is the fine-grained sediments, and that the migration into the coarser and permanently more porous horizons takes place at an early stage as the result of compacting. Many of these porous horizons are quite limited in their lateral extent, so that the later migration as a result of tilting and folding movements is often limited, unless abnormal conditions such as faults and joints produce planes of egress for the gas or oil. Hence it is found that as a result of variations in porosity and of irregular deposition of sandy horizons, the primary migration due to compacting is often of more importance in the differentiation of oil into pools than the later earth movements, which merely localize the oil and gas in the higher portions of the more porous strata. Of course, in many cases, the coarse horizons are sufficiently widespread to allow the anticlinal hypothesis to hold, but the reverse is more common in nature than is usually suspected.

V. C. I.

VII.—Geology and Ore Deposits of Rossland, British Columbia. By Charles Wales Drysdale. Memoir 77 of the Geological Survey. Ottawa, Government Printing Bureau, 1915. pp. xiv + 317, with 6 maps in pocket, 25 plates, and 26 figures in the text.

The rich district of Rossland, which is situated in the Trail Creek mining district of the West Kootenay district of British Columbia, about 6 miles west of Columbia River and 5 miles north of the International Boundary, produces gold, silver, and copper. It was discovered in 1890, and has been worked continuously since 1894. In this memoir the region is very fully described. The geological features and the mineral enrichment, which present many points of interest, are discussed in some detail. The district appears to have been covered by sea during at least part of the Carboniferous age, and upheaved at the end of the Palæozoic era. An intrusion of augite porphyry occurred during the Triassic period, and at the close of the Jurassic period the rock formations were invaded by the Trail granodiorite batholith, this being the first period of mineralization. Erosion took place throughout Cretaceous times, and at the end the whole Cordillera was uplifted and the present ranges were outlined. The second main period of mineralization occurred in Miocene time. During the Pleistocene a change to a glacial period took place. The ore consists of pyrrhotite, chalcopyrite, pyrite, and marcasite, with a little arsenopyrite, molybdenite, and bismuthinite, in a gangue of altered country rock, containing some quartz and locally a little calcite. The deposits resemble in many respects the well-known ones at Namaqualand, Cape Colony, and possess some structural features in common with those at Butte, Montana.

VIII.—United States Survey: Rhode Island Coal.

In Bulletin 615 of the U.S. Survey, Mr. George H. Ashley gives an account of Rhode Island Coal, the interest of which is mainly economic, the conclusion being drawn that the coal cannot compete with that produced by New England and Pennsylvania. The coal has an unusually large range, character, and quality, varying from anthracite to graphite, and contains a high percentage of ash and moisture. The coal beds, which were originally of moderate thickness, have been so folded and compressed that, while in places large pockets have been formed, elsewhere they have been nearly altogether squeezed out. The coal ignites slowly and with difficulty, and makes so hot a fire as to destroy stove tops and furnace linings.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

November 2, 1916.—Sir J. J. Thomson, O.M., President, in the Chair.

"On the Photographic Spectra of Meteorites." By Sir William Crookes, O.M., F.R.S.

Thirty rare earthy meteorites, mostly acquired through the courtesy of the British Museum Trustees, have been examined.

The paper first deals with a few novel features in the construction of the spectrograph. The instrument has a train of five double quartz prisms of the Cornu type, and an explanation of their action in preventing double refraction is given. The jaws of the slit are formed of transparent quartz prisms, cut and mounted in such a manner that the edges appear opaque to light. A device, called the *fixed slit system*, is described, by which all uncertainty caused by variation in the width of the slit in various experiments is removed. The aerolites were all examined for occluded gases, especially with negative results for any inert gases that might be present. The spectrum tubes showed only compounds of hydrogen, carbon, and sulphur, and a little free hydrogen. The arc spectrum of each aerolite has been photographed from the region of the ultra-violet to the end of the visible.

The aerolite was powdered, mixed with powdered silver of known purity, and formed into a cake by hydraulic pressure. This gives sufficient cohesion for manipulation and enables it to conduct the current. The resulting spectrum contains, in addition to the lines of the aerolite constituents, only those due to silver, which are comparatively few. Examples of these spectra were exhibited.

All the lines given in the arc spectra of the thirty aerolites have been identified, and were shown in the spectrum photographs. The examination has revealed the presence of unexpectedly large traces of chromium in all the specimens, a condition quite different to that found in the siderites or meteoric irons, where chromium is practically absent.

The proportion between chromium and nickel remains constant in twenty-six out of the thirty aerolites, and is clearly shown in the photographs. In three only nickel is almost absent.

From the experience gained it has been possible to make a mixture containing known quantities of nickel and chromium, which with the addition of iron produces a spectrum in the neighbourhood of the chromium group that is practically identical with that produced by the aerolite *Aubres.*

II.—Zoological Society of London.

November 21, 1916.—Dr. S. F. Harmer, M.A., F.R.S., Vice-President, in the Chair.

"On the development from the matrix of further parts of the skeleton of the *Archæopteryx* preserved in the Geological Department of the British Museum (Natural History)."

Dr. B. Petronievics and Dr. A. Smith Woodward, F.R.S., V.P.Z.S., read a paper on some new parts of the pectoral and pelvic arches lately discovered in the London specimen of *Archæopteryx.* The coracoid bone most closely resembles that of the ratite birds and the Cretaceous *Hesperornis.* The pubic bones are twice as long as the ischia and meet distally in an extended symphysis, gradually tapering to a point, which seems to have been tipped by a mass of imperfectly ossified cartilage.

III.—Edinburgh Geological Society.

November 15, 1916.—Professor Jehu, Vice-President, in the Chair.

The following papers were read:—

1. "A New Locality for Triassic Reptiles, with Notes on the Trias found in the Parishes of Urquhart and Lhanbryde, Morayshire." By Mr. William Taylor, J.P., Lhanbryde.

Mr. Taylor recorded the discovery, in sandstones about a mile north of the village of Urquhart, of a nearly complete specimen of *Telerpeton*, somewhat smaller than the example described by Huxley in 1866.

On account of lithological resemblances he correlated the sandstones, etc., of Bearshead, Stonewells, Meft, Lhanbryde, and New Elgin with the fossiliferous rocks of Lossiemouth and Spynie, and concluded that the Trias of Morayshire was much more extensive than formerly supposed.

The paper was illustrated by a map showing the distribution of the Triassic rocks in the area extending from Lossiemouth and Bearshead southwards to New Elgin and Lhanbryde. On the map were recorded the genera of reptiles found at the various fossiliferous localities.

2. "Volcanic Necks in North-West Ayrshire" (with lantern illustrations). By G. V. Wilson, B.Sc., H.M. Geological Survey.

The area between Dalry, Ardrossan, and Largs contains the sites of about thirty volcanoes. In the north the large volcanic centre of Misty Law is most probably of Calciferous Sandstone age, and gave rise to the lava-flows of that period in the district. The area to the south is studded with a number of volcanic necks, all of which contain ash of a type similar to the interbedded ashes which occur about the position of the Dalry Blackband Ironstone; it was suggested that some of the necks gave rise to these beds of ash. One neck was described in which occurred a fallen mass of a coal-seam which had been large enough to work; fragments of charred wood and rounded pebbles of biotite, hornblende, and augite also occur in this neck. In another case marine shells—of a type not later than Millstone Grit—had been found in the ash of a neck, probably washed into the crater of a submarine volcano or into one on low-lying ground liable to submergence. This phase of volcanic activity probably started soon after the deposition of the Lower Carboniferous Limestones, and continued intermittently till Millstone Grit times, with quiescence during the deposition of the Coal-measures; but farther to the south we have the remains of great volcanic activity during the Permian. It was suggested that the district at its period of volcanic activity may have resembled, in some ways, the San Franciscan Volcanic Field of Arizona.

IV.—Geological Society of London.

1. *November* 22, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read:—

"Characeæ from the Lower Headon Beds." By Clement Reid, F.R.S., F.L.S., F.G.S., and James Groves, F.L.S.

The investigations here recorded have been made at Hordle Cliffs (Hampshire), where the strata, below the superficial gravel, belong entirely to the Lower Headon Beds, and consist of freshwater and brackish-water (more or less calcareous) deposits, laid down apparently in wide shallow lakes and lagoons. Such habitats are the most favourable to the growth of Characeæ, and several of the beds have yielded numerous remains of these plants.

There is a great diversity in the fruits of *Chara* found, representing evidently a number of species, belonging to several different sections or genera. With the exception of a few, which are possibly abnormal variations, the fruits can be roughly grouped under the following types:—

I. Tuberculate series. (Type of *C. tuberculata*, Lyell = *Kosmogyra*, Stache, emend.)
- (*a*) Spherical.
- (*b*) Obovoid or pyriform, with distinctly prolonged base.

II. Non-tuberculate series.
- (*c*) Large spherical, diam. *c.* 1 mm. (type of *C. medicaginula*, Brongn.).
- (*d*) Large ellipsoidal (type of *C. helicteres*, Brongn.).
- (*e*) Medium-sized, subglobose, tapering more or less at both ends.
- (*f*) Cylindric-ellipsoidal, showing more numerous striæ.
- (*g*) More or less pyriform: that is, definitely tapering towards the base.
- (*h*) Minute, subglobose-ovoid (long. = *c.* 350 to 500 μ).

It is difficult to determine the exact number of species found, on account of the extreme variability of some of the forms, but the authors consider that at least twelve may, for the present, be conveniently treated as distinct.

The vegetative remains are comparatively few, consisting of minute portions of stems and branchlets of different diameters, and these it is impossible at present to connect with any particular types of fruit.

Though investigations of some earlier formations have shown that there are extinct forms of Characeæ exhibiting important points of difference from their living representatives, the remarkably distinct and characteristic oogonium of five elongated spirally twisted cells has remained constant certainly as far back as the Inferior Oolite, and it is only in earlier formations that any doubt arises as to whether bodies are or are not *Chara* fruits.

Characeæ are found in still fresh or brackish water all over the world, under widely different conditions as regards heat, etc., and may therefore be expected to occur in almost all freshwater formations.

For these reasons it is suggested that the fruits of this group of plants, when more widely collected, may prove of considerable value as zonal fossils for the correlation of lacustrine deposits lying in isolated basins. Doubtless, on account of their small size, the Characeæ have in the past often been overlooked.

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2. *December* 6, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

Mr. G. C. Crick, A.R.S.M., F.G.S., gave an account of some recent researches on the Belemnite animal. He stated that it was not his intention to deal that evening with the homologies of the Belemnite shell or with the phylogeny of the Belemnite group, but to confine himself to the restoration of a typical Belemnite animal and its shell, as shown particularly by examples in the British Museum collection.

He first demonstrated, by means of a rough model, the construction of the Belemnite shell, including the guard or rostrum, the phragmocone with its ventrally situated siphuncle, and its thin envelope the conotheca, with its forward prolongation and expansion (on the dorsal side) known as the pro-ostracum. He then exhibited photographic slides of examples in the British Museum collection showing these various characters, and noted the abrupt termination of the chambered cone on the lower part of the pro-ostracum, of which the dorsal surface may have been partly or almost completely covered by a thin forward extension of the guard. To illustrate what was known of the complete body of the animal as found associated with the guard, he then showed photographic slides of two of the examples figured by Huxley in his *Memoir on the Structure of the Belemnitidæ* published in 1864. Each of these exhibited the guard associated with portions of the pro-ostracum, the ink-bag, and the hooklets of the arms. The form of the hooklets with their thickened bases was discussed, this feature in a great measure justifying the attribution to the Belemnite of certain Cephalopod remains (found practically at about the same geological horizon) that included uncinated arms associated with an ink-bag, and frequently also with nacreous portions of (presumably) the pro-ostracum.

Of the remains of uncinated armed Cephalopods from the Lias, each exhibiting the same form of hooklets as those figured by

Huxley, he said that the British Museum collection contained seventeen examples, all from the neighbourhood of Lyme Regis and of Charmouth, in Dorset. Each specimen exhibits a number of uncinated arms associated usually with an ink-bag, sometimes also with nacreous matter, and in two instances also with the guard or rostrum. These two examples were those to which he had already referred as having been figured by Huxley, and unfortunately the arms are not well preserved in either of these specimens; in one (*B. bruguierianus*, from the Lower Lias near Charmouth) there are only a few scattered hooklets, while the arms of the other (*B. elongatus*, from the Lower Lias of Charmouth) are represented only by a confused mass of hooklets. Of the other fifteen examples, in one there are a few solitary hooklets; in another the number of the arms is very indistinct; in two the remains of only two arms are preserved; in one there are traces of three arms; in two there are indications of three, or possibly four, arms; in one there is a confused mass of possibly four arms; and in one there are the remains of four, or possibly of five, arms. In each of the remaining six specimens six arms can be more or less clearly made out, while there is not a single example in which more than six uncinated arms are displayed.

Of the six examples that exhibit six uncinated arms four are stated to be from the Lias of Lyme Regis; one is from the Lias of Charmouth; and one was obtained from the Lower Liassic shales between Charmouth and Lyme Regis. From a consideration of these specimens, the speaker concluded that the Cephalopod represented by these uncinated arms is the animal known as the Belemnite, and that the six uncinated arms were arranged in three pairs of unequal length, of which the longest pair was lateral, the medium-sized pair probably dorsal, and the shortest pair probably ventral. He considered the presence of tentacular arms to be doubtful. These observations were in accord with those of Huxley, who, in his *Memoir* already cited, stated that he had "not been able to make out more than six or seven arms in any specimen, nor has any exhibited traces of elongated tentacula, though the shortness of the arms which have been preserved would have led one to suspect their existence".

Mr. Crick regarded certain markings sometimes to be seen on the guard as indicating that during the life of the animal the guard was almost, if not entirely, covered by the mantle, in which case it was highly improbable that the guard was pushed into the soft mud of the sea-bottom in order to act as an anchor.

He considered the animal to have been a free swimmer, swimming forward ordinarily, but when desirable, capable also of sudden and rapid propulsion backwards.

V.—Liverpool Geological Society.

1. The first meeting of the fifty-eighth session of this Society was held on October 10 last, Mr. J. H. Milton, F.G.S., F.L.S., President, occupying the chair. The report on the work of the past session

showed that in spite of present adverse circumstances there had been a slight increase in the membership, and that the activities of the Society had been well maintained.

The President in his annual address dealt with "The Coral Types of the Carboniferous Limestone", and gave a very valuable and helpful résumé of the principal diagnostic characters of the different genera. The lines of their evolution were traced, and their value as zonal indices clearly shown. In this connexion a warm tribute was paid to the work of the late Dr. Arthur Vaughan. The address was fully illustrated by a beautifully drawn series of sections of the chief types, and an excellent collection of specimens from North Wales and elsewhere.

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2. *November* 14, 1916.—J. H. Milton, F.G.S., F.L.S., President, in the Chair.

The following paper was read:—

"The Pebbles of the Middle Bunter Sandstones of the Neighbourhood of Liverpool." By T. A. Jones.

The author described the results of an investigation into the nature of the rock types represented amongst the pebbles, which he roughly classified under the following heads: Quartzites and Grits, Granites, Mica Schist, Felstones, Tourmaliniferous Quartzites, Grits, Schists, etc., Fossiliferous Pebbles, and Miscellaneous. Attention has been given chiefly to those bearing tourmaline, which collectively were present in greater abundance than those of any other group, with the exception of the Quartzites and Grits. The mineral was present in great variety and quantity, and on the whole the rocks showed marked similarity to those surrounding the granite masses of Devon and Cornwall, with which they were perhaps still more strongly linked by the discovery of a pebble of granite containing abundant tourmaline in slender prisms, and small pinkish garnets. This rock when crushed yielded splintery fragments of dark indigo blue tourmaline, closely resembling those found amongst the heavy density minerals of the finer material of the Triassic sandstones of the district. A light ash-grey friable schist was also described, which contained irregular grains of brown and blue tourmaline apparently of clastic origin, which was also considered competent to have furnished some of them.

Three other varieties of biotite granite were found, two of them with micropegmatitic structure. Twelve varieties of felstones had been examined, all of acid type. Four contained tourmaline plentifully, and two seemed to be tuffs rather than lavas. Among the fossiliferous pebbles one of reddish quartzite containing a single specimen of a small *Orthis* was recorded, the only example so far known to the author from the local pebble beds.

On the whole the assemblage of pebbles seemed substantially identical with those of the Midlands as described by Professor Bonney, although the tourmaliniferous group was judged to be of greater importance. The paper closed with a brief discussion of the possible sources of the pebbles, and the method of transport.

3. *December* 12, 1916.—J. H. Milton, F.G.S., F.L.S., President, in the Chair.

Mr. H. C. Beasley and Professor J. W. Gregory, D.Sc., F.R.S., were unanimously elected honorary members. Mr. Beasley has been an ordinary member for the last forty-six years, during which period he has been one of its foremost working members, and it has been a great pleasure to his fellow-members to recognize his great services to the Society and to local geology.

The recent announcement of the gift of a Chair of Geology to Liverpool University by Professor and Mrs. Herdman, as a memorial to their son, was referred to with much interest and sympathy, and the following resolution was approved: "That this Society has learned with much satisfaction of the intended establishment of a Chair of Geology in the Liverpool University, and has special pleasure in the fact that the establishment is due to the generosity of one of its members and past presidents, Professor Herdman, and Mrs. Herdman, by whose action the long-felt need for the due recognition of this subject in the University scheme will at length be satisfied."

Mr. C. B. Travis, in a "Note on Terminal Curvature at Billinge Hill", described an interesting example to be seen near the summit of the hill, where the outcropping beds of the Lower Coal-measures are curved over in a remarkable manner by the onward pressure of the Irish Sea ice-sheet invading the district from the west. This section has not previously been described.

Mr. F. T. Maidwell followed with an account of recent geological rambles about Liverpool, in which he threw fresh light on some old sections. The correlation of the coal-seams in the collieries at Neston, Cheshire, was dealt with at some length, also the little-known outcrop of Permian strata at Skillaw Clough near Bispham.

VI.—The Wellington, New Zealand, Philosophical Society (Geological Section).

The annual meeting of the Wellington Philosophical Society (Geological Section) was held last evening, September 20, 1916, at the Dominion Museum. Mr. G. Hogben, C.M.G., F.G.S., presided. The Annual Report stated that during the year seven meetings had been held, with an average attendance of fourteen. The following papers have been read: "A Phase of Shore-line Erosion," by Mr. J. A. Bartrum; "Terminology for Foraminal Development in Terebratuloids," by Mr. S. S. Buckman, F.G.S.; "The Continental Shelf" and "The Motion of Water in Waves", by Dr. C. A. Cotton, F.G.S.; "The Geological Occurrence and Origin of Petroleum," by Messrs. W. Gibson and M. Ongley; "The Structure of the Paparoa Range," by Dr. J. Henderson; "An Artesian Trial Bore at the Westshore, Napier," by Mr. R. W. Holmes; "Notes of a Visit to Marlborough and North Canterbury," by Mr. P. G. Morgan, F.G.S.; "Stage Names applicable to the Divisions of the Tertiary in New Zealand," by Dr. J. A. Thomson, F.G.S.; "The Volcanic Rocks of Oamaru," by Mr. G. Uttley, F.G.S.

The election of office-bearers for the ensuing year resulted as follows: Chairman, Dr. C. A. Cotton, F.G.S.; Vice-Chairman, Dr. J. Henderson; Hon. Secretary, Mr. E. K. Lomas; Committee, Messrs. Morgan, F.G.S., Ongley, Uttley, F.G.S., Holmes, and Dr. Thomson, F.G.S.

During the evening Dr. J. Allan Thomson read papers: (1) "On the so-called 'Drift Formation' of Hawera"; (2) "The Geology of the Middle Clarence Valley, between the Bluff and Herring River." —*New Zealand Times*, September 21, 1916.

OBITUARY.

CLEMENT REID, F.R.S., F.L.S., F.G.S., Etc.

Born July 6, 1853. Died December 10, 1916.

It is with the deepest regret that we have to record the death of Mr. Clement Reid, late of H.M. Geological Survey, which took place at his residence, One Acre, Milford-on-Sea, on Sunday, December 10. He was buried at Milford on the following Wednesday. Mr. Reid was so deeply versed in all matters relating to the later Tertiary and more recent strata that all geologists interested in these deposits will feel that their science has lost a master and they a reliable co-worker. Only those who knew Mr. Reid intimately could appreciate his sterling abilities and intense devotion to his scientific work, characteristics in which he so much resembled his great-uncle Michael Faraday.

Mr. Clement Reid joined H.M. Geological Survey in 1874 and started work, under the able guidance of H. B. Woodward, in the South-West of England, but in 1876 was transferred to Norfolk, and there began, under the same genial leader, the detailed study of the Pliocene and Pleistocene deposits, including the "Forest Bed" and "Contorted Drifts", of the Norfolk coast. The name of Clement Reid has ever since been intimately connected with the study of these formations; indeed, in all matters relating to the "Norfolk Forest Bed" and the nearly associated strata he was regarded as the chief authority. His memoir on *The Geology of the Country around Cromer* (Explanation of Sheet 68 E.), together with the maps and sections, is a model of careful work, and exemplifies the close attention to minute details as well as the broad grasp of his subject which has ever characterized his scientific work.

Mr. Reid published numerous papers on geological subjects, many of which are of more than ordinary interest; but as an officer of H.M. Geological Survey his chief work was the preparation of maps and of explanatory memoirs, and for this purpose after leaving Norfolk he was engaged in later years in Yorkshire, Lincolnshire, Sussex, Hampshire, Isle of Wight, Dorset, Wilts, Cornwall, and the London area. It is therefore in the publications of the Survey that the bulk of Mr. Reid's work will be found, and these chiefly relating to Tertiary and more superficial deposits.

Whatever Mr. Reid undertook to do he did thoroughly. He was always a most careful and untiring worker, and even his times of relaxation were devoted to some collateral aspect of his work. The palæontological side of his investigations always gained his close attention. Quite early in his career he made botany a special study. Certain seeds found in the "Forest Bed" needed determination, and he began, for comparison, to collect the seeds of wild plants, which seem at that time to have been strangely neglected, with the result that he became perhaps the first authority on the subject, and showed how much information regarding the climate of former times was to be obtained from fossil seeds. The painstaking work of himself and Mrs. Reid in the investigation of seeds laboriously washed out from certain deposits has resulted in the joint publication of memoirs which may be regarded as monumental ("The Fossil Flora of Tegelen-sur-Meuse," Verhandl. d. Kon. Akad. v. Wetenschappen te Amsterdam, 1907; "The Preglacial Fauna of Britain," Journ. Linn. Soc. Botany, 1908; *The Pliocene Floras of the Dutch–Prussian Border*, published by the Institute for the Geological Exploration of the Netherlands, The Hague, 1915). Mr. Reid's report upon the Pleistocene deposits at Hoxne was largely based upon the seeds found in the more peaty parts of these beds. An exceedingly interesting study of fossil Characeæ was in progress by Mr. Reid at the time of his death in conjunction with Mr. J. Groves, but the results have only just begun to be published. This work seems to have been initiated by the examination of silicified slabs of Purbeck rock showing beautifully preserved sections of Chara stems, which led Mr. Reid to try artificial weathering by weak acid on some impure limestones, and this led to important discoveries in regard to anomalous structures in some of these fossils (see Proc. Roy. Soc., B, vol. lxxxix, p. 252, 1916). More recently, also in co-operation with Mr. J. Groves, the Chara seeds from the Headon Beds, near his home at Milford, were investigated, and a most important paper on the subject was read before the Geological Society only a week or so ago, and will, we hope, be published before long.[1]

Mr. Clement Reid was elected a Fellow of the Geological Society in 1875, was awarded the Murchison Geological Fund in 1886, and the Bigsby Gold Medal in 1897. He served for two periods on their Council, and was Vice-President in 1913–16. He was elected a Fellow of the Linnean Society in 1888, and served two periods on the Council. In 1899 he was elected a Fellow of the Royal Society. The Royal Geological Society of Cornwall awarded him the Bolitho Gold Medal in 1911.

Mr. Reid, having joined H.M. Geological Survey in 1874, was advanced to the post of "Geologist" in 1894, became "District Geologist" in 1901, and retired in January, 1913. Mr. Reid married Miss E. M. Wynne Edwards in 1897, and upon his retirement went to live at his new residence at Milford-on-Sea, where, after only three short years, he passed peacefully away in the closing month of the year 1916.

[1] See Reports and Proc. Geol. Soc. Lond., *ante*, p. 42.

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

ASSISTED BY

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FEBRUARY, 1917.

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THE
GEOLOGICAL MAGAZINE
NEW SERIES. DECADE VI. VOL. IV.

No. II.—FEBRUARY, 1917.

ORIGINAL ARTICLES.

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

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

(*Continued from Dec. VI, Vol. III, p. 435.*)

(PLATE III.)

Membranipora crateroides, sp. nov. (Pl. III, Figs. 1 and 2.)

Zoarium unilaminate, incrusting.

Zoœcia large and pentagonal, average length about ·8 mm., markedly crater-shaped (i.e. with side walls sloping inwards to a deep-lying areal opening): areas sub-pentagonal as a rule: side walls wide, sloping inwards practically all the way from the zoœcial margin, the slope gentle in the lower half, then changing gradually to quite steep at the upper end; the two upper corners are occupied by a pair of stumpy perforated tubercles; just below the summit of the steep inward slope at the upper end of the arc, close to the corners and probably communicating with the external tubercles, are two pores so faint as to be hardly visible in full light.

Oœcia very large even for zoœcia of this size, and very globose; the only well-preserved specimens yet obtained have a jagged free edge which probably was once straight or slightly concave.

Avicularia very abundant; practically every zoœcium that has not an oœcium has above it a small, often sharply, equilaterally triangular accessory avicularium with well-preserved crossbar; in addition there are a number of sub-vicarious mandibular avicularia scattered irregularly about, and ranging from fully developed forms about ·45 mm. in length with the upper part of the beak expanded and rounded off down to forms about ·3 mm. in length with a short blunt beak projecting but little beyond a somewhat inflated body; occasionally these pass into a very remarkable form (Fig. 1) consisting of a greatly inflated body embracing the whole of a short beak and standing almost vertically on end.

This species is distinguishable from *M. trigonopora*, Marss.,[1] by its sub-vicarious avicularia and perhaps its oœcia, as none are recorded for Marsson's species, but they are obviously closely related. Like the species described in the previous paper it is prominent in the Weybourne Chalk; but it also occurs in the Norwich Chalk.

[1] Loc. cit., p. 58, t. v, fig. 16.

MEMBRANIPORELLA TÆNIATA, sp. nov. (Pl. III, Figs. 3 and 4.)

Zoarium unilaminate, free or incrusting.

Zoœcia very long, average length 1·2 to 1·3 mm., separated by a broad common wall running like a continuous ribbon between the lines of zoœcia and expanding to a great width between successive zoœcia: front wall pierced by numerous pairs of long very slender slits, the upper of which nearly meet in the middle line (in the early stages, Fig. 4, they may be much wider), highly arched, and rising steadily up to the greatly thickened final bar which forms the lower lip of the aperture and is markedly V-shaped and rests on the side walls distinctly beyond the areal margin: aperture large, roughly circular, but with straight sides which pass under the lower lip at a slight but distinct angle.

Oœcia apparently absent, which indicates affinity with the *Cribrilina Gregoryi* group.

Avicularia occurring freely embedded in the common wall; the great majority are of the small mandibular type characteristic of *Cribrilina Gregoryi*, and are arranged roughly in pairs above and below each aperture with others scattered about irregularly; but here and there occur much larger inflated and elongated forms with the aperture wholly in the upper half.

This species occurs in Hants in the upper part of the (restricted) zone of *A. quadratus*, but is quite rare.

MEMBRANIPORELLA BITUBULARIS, sp. nov. (Pl. III, Figs. 5 and 6.)

Zoarium unilaminate, free or incrusting.

Zoœcia long and narrow, average length ·8 to ·9 mm.: side walls often more or less distinct, but on the whole fused into a broad common wall which spreads out to a great width at the foot of the zoœcium and slopes gently down to the aperture of the preceding zoœcium: front wall flatly arched, pierced by numerous pairs of slits of which about the upper four are parallel and the remainder radiate, springing from just inside the top of the side walls and rising from the foot to within a short distance of the aperture, when it sinks again rather rapidly: aperture terminal, heel-shaped, and deeply sunk, with the straight lower lip thickened, but no thickened rim to the upper lip, much overshadowed, together with the side wall for some way above it, by lateral avicularia.

Oœcia absent, as is only to be expected in a species with such obvious affinity to *Cribrilina Gregoryi*.

Avicularia very regularly present in pairs on either side of the aperture as well as scattered irregularly along the side walls: the apertural pairs might be regarded as single rather large rounded accessory avicularia with abnormally stout crossbar in an unusually central position, but I think it much more probable that they are pairs of rudimentary avicularia in contact which have fused along the contact, the lower one being as a rule distinctly the larger.

This species is one of the very few which can be satisfactorily recognized among the various forms of this group, small numerically but great in variability, which occur in the *M. cor-testudinarium* zone of Sussex. The two specimens figured, of which the original of

Fig. 5 is the more typical, show how much variation is possible within the species.

CRIBRILINA TUMULIFORMIS, sp. nov. (Pl. III, Figs. 7 and 8.)

Zoarium unilaminate, incrusting.

Zoœcia very variable in shape, but on the whole long and very narrow for their length, like graves, often running to ·7 mm. in length with a breadth of only ·3 mm.; no side walls visible: front wall arched, with a sharply defined median ridge and numerous pairs of imperforate furrows which are very faint but seem to run nearly up to the median ridge; these furrows persist along the sides of the aperture: aperture terminal and small in proportion, without any thickened margin, almost circular with short and straight lower lip and a sub-quadrate upper lip with very faint upper angles and a very slight convergence to the lower lip; sometimes the lower lip is concave and the aperture is then practically circular; a pair of tiny tubercles occur at the upper angles, but are generally difficult to detect except when they have been absorbed by the oœcia (for which they act as starting-points) and re-exposed on the oœcia breaking. There is a communication slit at the extreme upper end.

Oœcia very abundant, elongated, slightly of the water-bottle type (with a constricted neck just above the aperture), and slightly pointed at the upper end, aperture small and semicircular, free edge distinctly concave; in a favourable light it can be discerned that these oœcia are ribbed like the zoœcia.

Avicularia do not appear to occur.

This species occurs sparingly in the *M. cor-anguinum* zone and the *Uintacrinus* band in Kent. It seems obviously an ancestor of *Cribrilina Filliozati*, Bryd.[1]

CRIBRILINA SEAFORDENSIS, sp. nov. (Pl. III, Fig. 9.)

Zoarium unilaminate, incrusting.

Zoœcia short and broad, average length ·4 mm.: no side walls visible, but from broken specimens they appear to remain quite distinct: front walls arched with numerous pairs of broad furrows, all radiating, which nearly reach the middle line, but are quite shallow and inconspicuous except near the margin, where they deepen rapidly: aperture terminal, lower lip formed by the slightly thickened terminal bar of the front wall, which is sometimes straight, sometimes gently concave; upper lip formed by a flatly curved segment of the unthickened side wall and bearing a pair of strong imperforate tubercles immediately adjoining the lower lip and in obvious continuation of the bases of those spines which have formed the front wall; above these tubercles the upper lip may bear, when there is no oœcium, one or two or even occasionally three minor tubercles; if there is an oœcium it starts immediately above the principal tubercles, and the lip of the aperture is cut away below it.

Oœcia rather large, globose on the whole but nearly straight-sided in the lower part; free edge slightly concave.

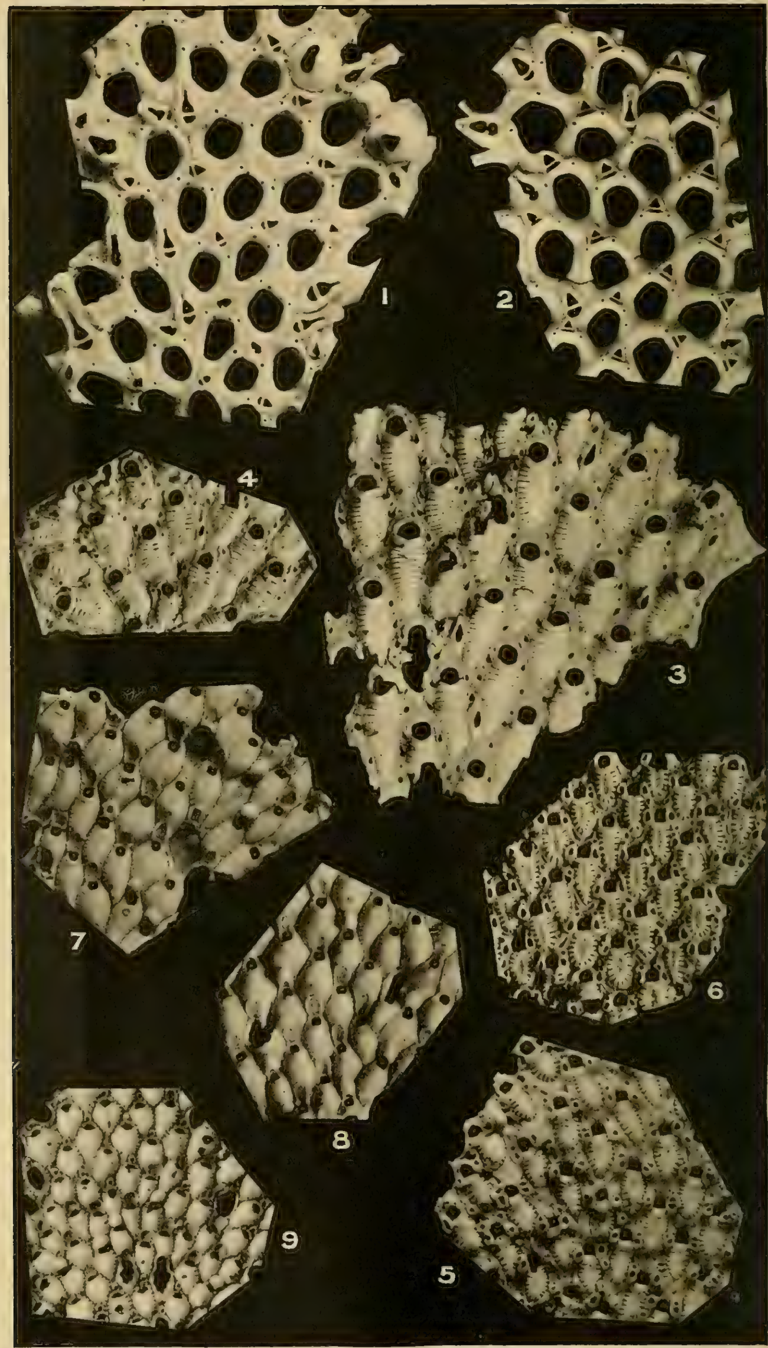
[1] GEOL. MAG., 1910, p. 391, Pl. XXX, Figs. 9, 10.

Avicularia tiny hoods with circular apertures placed immediately above the zoœcia in the middle line with great regularity when no oœcium occurs; when there is an oœcium the avicularium is suppressed or, very occasionally, displaced to one side; one or two instances in which they appear to have no aperture are probably due to the aperture being blocked by a fragment of shell.

This species is rare in the *M. cor-testudinarium* zone at Seaford. It illustrates well the building up of the Cribrilinid front wall from marginal spines, the bases of the spines being still distinguishable. It is probably ancestral to *Cribrilina cicatricifera*, Bryd.[1]

Since the above paper was framed I have seen Mr. Lang's Revision of the "Cribrimorph" (i.e. Cribrilinid) Cretaceous Polyzoa in *Annals and Magazine of Natural History* for July and November, 1916. I am glad to find that he adopts the view I propounded in 1906 (Geol. Mag., July, 1906, p. 289) that the characters by which the genera *Cribrilina* and *Membraniporella* are distinguished are not of generic nature. In replacing this principle of classification he has created over fifty new genera. It would obviously be a considerable task, for which I neither have time nor claim authority, to sit in judgment on such a volume of new material, particularly as it is not accompanied by a single illustration, and many of the new genera do not rest on any species figured elsewhere. It is fairly open to doubt whether as a rule any verbal description of characters among forms so small, numerous, and complex as the Polyzoa can be relied on as adequate definition of a new genus. The same consideration applies with even greater force to the very great number of new species which he catalogues without figuring any of them. It is not too much to say that the most detailed diagnosis without reference to a figure is now insufficient to identify any form among the vast crowd that either have already been adequately described or still remain to be so described. Mr. Lang's catalogues certainly do not amount even to detailed diagnosis, and it is impossible to treat his new species as identified sufficiently to be accepted as validly established. When they have been figured they will be sufficiently definite for useful study; but a cursory inspection of the catalogues suggests that some of them may have a hard struggle for existence unless the points which appear in the tabular diagnoses are substantially supplemented. It gives, for instance, a very retrograde impression to find unilaminar forms of *Cribrilina Gregoryi* divided solely by whether they grew incrusting an imperishable object or are now found free into two species (perhaps to be increased to three on Mr. Lang observing that though the majority of the free forms have a prickly reverse side a substantial minority are smooth). I shall also be much surprised if there should prove to be a bilaminar race of *Cribrilina Gregoryi*, that is, something more than an isolated freak or a unilaminar zoarium which has happened to incrust rather neatly the reverse side of a free unilaminar zoarium, at the horizon with which of all Chalk horizons I am perhaps most familiar.

[1] Geol. Mag., 1914, p. 97, Pl. IV, Figs. 1, 2.



R. M. Brydone, Photo. Bemrose, Collo.

Chalk Polyzoa.

EXPLANATION OF PLATE III.

(All figures × 12 diams.)

FIG. 1.	*Membranipora crateroides.*	Zone of *B. mucronata.*	Weybourne.
,, 2.	,, ,,	,, ,,	Norwich.
,, 3.	*Membraniporella tæniata.*	East Dean, Hants.	
,, 4.	,, ,,	Shawford, Hants.	
,, 5, 6.	,, *bitubularis.*	Seaford.	
,, 7.	*Cribrilina tumuliformis.*	Zone of *M. cor-anguinum.*	Leaves [Green, Kent.
,, 8.	,, ,,	,, ,,	Gravesend.
,, 9.	,, *Seafordensis.*	Seaford.	

II.—The Age of the Maitai Series of New Zealand.

By C. T. Trechmann, M.Sc., F.G.S.

(PLATES IV AND V.)

Previous Views on the Age of the Maitai Series.

THE question of the age of the Maitai Series is one of the most important which concern New Zealand geology, and one which has aroused the greatest controversy and uncertainty. F. von Hochstetter,[1] before any distinctive fossils had been found in these rocks, considered that the "Maitai Series", which form the hills bounding on the east and south-east the strip of fossiliferous Trias of the Nelson area, were of Triassic age, and underlay the sandstones with *Monotis salinaria.*[2] In 1873 F. W. Hutton[3] referred the Maitai to the Jurassic on the supposed occurrence of *Inoceramus*. A. McKay[4] in 1878, during the survey of the Nelson district, found several fossils, obviously of late Palæozoic age, in the Maitai Limestone of the upper part of the lower Wairoa Gorge opposite a place called Martin's Saw-mill. Sir J. Hector[5] identified these as *Spirifera bisulcata*, *Productus brachythærus*, *Cyathophyllum*, and *Cyathocrinus*. McKay also surveyed and collected from the Maitai slates and argillites at Wooded Peak, on the Dun Mountain Tramway, some five miles east of Nelson. A large bivalve shell having the prismatic structure and general outline and concentric plication of *Inoceramus* occurs here. McKay, however, in his report adds that "there are material differences between this shell and the ordinary forms of *Inoceramus* which may warrant its being considered the type of a new genus". These words are of great importance, since he clearly states his conviction that fragments of a prismatic shell which occur with the Carboniferous fossils in the Maitai Limestones belong to the same shell as that which occurs in the slates on Wooded Peak. There can be no question but that it is the same shell. Since the finding of the above-mentioned fossils the Palæozoic age of the Maitai Series does not seem to have been seriously questioned till 1903, when Professor J. Park[6] stated his opinion that the Maitai Series

[1] F. von Hochstetter, *New Zealand*, 1867, p. 57.
[2] Now known as *Pseudomonotis Richmondiana.*
[3] Reports of Geol. Explorations, 1873–4, p. 34.
[4] Reports of Geol. Explorations, 1877–8, issued 1878, pp. 124, 132.
[5] Reports of Geol. Explorations, 1877–8, Introduction, p. xii.
[6] "On the Jurassic Age of the Maitai Series": Trans. N.Z. Inst., vol. xxxvi, p. 431.

are of Jurassic age. The reasons for this were, among others, the apparently conformable dip of the Triassic *Mytilus problematicus* beds in the Wairoa Gorge beneath the Maitai Limestone; the supposed equivalence of the Maitai Limestone with the Kaihiku Beds of Eighty-eight Valley; and the failure to find fossils in the Maitai Limestone. In 1910, however, Park,[1] after examining the limestone fossils collected by McKay in 1878, returns to the view that the Maitai Limestone is Carboniferous. He still, however, expresses doubts on the *Inoceramus* question, and says that "a careful search was made for fossils at the place where *Inoceramus* was said to occur, but without success". Some calcite-filled contraction rents were, however, found in the rocks, and it is suggested that McKay might have mistaken these for fossils. In 1911 a report[2] on the re-survey of the Dun Mountain district of Nelson by J. M. Bell, E. de C. Clarke, and P. Marshall appeared. In this report the whole of the Maitai Series, including its limestones, slates, argillites, and contemporaneous igneous rocks, together with the fossiliferous Trias of the district, including the Kaihiku, Oreti, Wairoa, and Otapiri Beds of the earlier reports, are included together as a conformable series of Trias–Jura age, and are spoken of as the Maitai Series. The inclusion together of all these beds was due partly to the unfortunate fact that again the surveyors failed to detect the fossils in the Maitai Limestone previously recorded by McKay, but also because of the deceptive appearance of conformity between the Trias and the Maitai. P. Marshall in 1912[3] repeats his opinion that the rocks from the Dun Mountain to the Waimea Plain are a conformable series, but are sharply folded, and attributes a Trias–Jura age to the whole series.

In October, 1915, when I was in the Wairoa Gorge in company with Mr. F. Worley of Nelson, we made careful inquiries where "Martin's Saw-mill" formerly stood, as it had disappeared since 1878. On returning two days later with Dr. A. Thomson we had the good fortune almost simultaneously to find the fossils at the place indicated. I also found an exposure of the same limestone, on the bank of the Roding River, just above the point where it joins the Wairoa River, which showed the sections of a fair number of fossils on the water-worn surface of the rock. A fairly large collection was made here by Dr. Thomson and myself, and we obtained a few forms in addition to those found in 1878.

Two days later I visited, in Mr. Worley's company, the Dun Mountain tramway line, and at Wooded Peak, again following closely the instructions in McKay's report, we found the large bivalves, exactly as he had described, in the slaty argillites, just west of a limestone band which adjoins the great serpentine and dunite intrusion of the so-called Mineral Belt. Having found the fossils, I paid special attention to collecting hinges or other portions

[1] *Geology of New Zealand*, 1910, p. 50.

[2] *The Geology of the Dun Mountain Subdivision, Nelson*, Bulletin No. 12 (New Series), 1911, p. 21.

[3] *Handbuch der regionalen Geologie* (Heidelberg): New Zealand and adjacent islands. English reprint, Heft v, Bd. vii, Abt. i, p. 16.

which might decide the question whether the shell is really *Inoceramus* or not.

STRUCTURE AND TECTONICS.

The Maitai Beds are a series of great structural importance since they, or at any rate rocks referred to this series on lithological and stratigraphical grounds, enter largely into the composition of the Alpine ranges of the South Island. It is only, however, in the Nelson district where fossiliferous limestones occur in the Maitai that any fossils other than the prismatic shell fragments and possibly some annelid tubes have been found in these beds.

McKay records nine localities where fragments of this prismatic shell have been found. Similar fragments occur in limestone on the Cass River and the Upper Waimakariri in the Canterbury Alps.[1]

The relation of the Mt. Torlesse annelid beds, which by the way are said not to occur actually at Mt. Torlesse, to the Maitai Series is one of the most difficult problems of New Zealand geology. McKay discusses this question,[2] and the general opinion seems to be that the annelid-bearing rocks belong to the upper part of the Maitai Series.

A great series of greywackes and other beds forms the ranges of the Rimutaka, Ruahine, and Tararua Mountains on the eastern side of the North Island. Dr. Thomson has recently found annelid remains in these beds near Wellington.

In other places the Maitai Beds become partly or completely metamorphosed. McKay[3] reports their occurrence in a semi-metamorphic condition in the heart of the Southern Alps west of Lake Whakatipu. When in this condition they are not easily distinguished from the underlying or partly equivalent Te Anau Series. However, both the Te Anau and the Maitai Series are newer than the rocks which at Mt. Arthur and Reefton contain a Silurian or possibly Devonian fauna.

McKay, after a detailed study of the Nelson area concludes, though with considerable reserve, that the Maitai Beds are arranged in a syncline with the main axis N.N.E. and S.S.W., in which case the limestone must underlie the slates and argillites of Wooded Peak. This limestone crops out near the top of the lower part of the Wairoa Gorge, where it forms the eastern boundary of the fossiliferous Trias beds. A limestone again appears on the eastern side of the slates and argillites on Wooded Peak, five miles east of Nelson, where, though unfossiliferous, it strongly resembles that of the Wairoa Gorge, and I have little doubt is the same bed.

No locality is known in New Zealand which reveals clearly the relation of the Trias to the beds underlying it. The Nelson area, the critical one for the study of the Maitai Beds, is very complicated. The Trias beds which form the foot-hills seem to consist of a long faulted synclinal strip, to the east of which, between them and the serpentine and dunite intrusion of the so-called Mineral Belt, the

[1] McKay, "Ashley and Amuri Counties": Rep. Geol. Expl. for 1879-80, issued 1881, p. 88.

[2] Ibid., pp. 89–90.

[3] Ibid., "Lake County," p. 142.

Maitai Beds, as remarked above, form another syncline. Both these parallel synclines appear to have been faulted and thrust over towards the west or north-west, with the result that the Trias appears to dip below the Maitai Limestone. Some zones of the Trias are locally missing through being faulted or thrust out, and the Tertiary beds which bound the Trias to the north-west along the edge of the Waimea Plains are forced up on end along the junction.

Lithology.

The Maitai Limestone in the Wairoa Gorge is much jointed, fissured, slickensided, and crushed, and has many veins running through it, which are sometimes seen to be repeatedly faulted on a small scale. Some parts are very impure, containing quartz grains and spots of a serpentinous or glauconitic mineral in such quantity that very little calcite remains and the rock becomes decalcified to a considerable depth. It is splintery in places but very hard in others. The greater part is unfossiliferous; the fossils appear to be confined to the upper part, where it adjoins the Maitai slates and greywackes to the east. Little clusters of prismatic shell fragments, however, occur lower down. The fossils are very closely incorporated with the rock, and are in consequence difficult to detach and are best collected in the decalcified portions. I had a slice made of a portion of the rock which contained a cluster of prismatic shell fragments (Plate IV, Fig. 8). It contains many fragments with corroded edges, and the surrounding matrix is also largely made up of isolated prisms of the decomposed shell which seem to be arranged round the larger pieces in a sort of flow-structure, or this may be a later pressure effect. A cross section of the prisms shows that they are more or less octagonal in outline. The matrix also contains quartz grains and chloritic specks.

The thickness of the limestone in the Wairoa Gorge is estimated at 2,000 feet,[1] but at Wooded Peak it is reduced to about 1,000, while southwards it gradually thins out and is finally represented by calcareous slates. It dips everywhere very steeply, often vertically. It seems impossible at present to estimate with any accuracy the thickness of the slates and argillites and the other beds which form the Maitai Series, but it is undoubtedly very great. The beds at Wooded Peak form a great series of hard, thinly bedded, well-jointed grey argillites, which dip everywhere nearly vertically. The large flattened shells are difficult to see and are easily overlooked on the weathered and moss-grown surfaces of the rock, but the sections of them can be detected on examining the joint faces, and the application of a hammer and chisel soon brings them to light. They are chiefly located along one or two bands quite near the adjoining limestone.

Fossils of the Maitai Rocks.

Aphanaia sp. (Pl. IV, Figs. 1–4.)

A glance at Figs. 1, 3, and 4 will show that the hinge of the large bivalve of Wooded Peak is not that of *Inoceramus*, but the genus of this shell is not easy to determine beyond doubt. I am of the

[1] McKay, "Report on the Wairoa and Dun Mt. Districts": Rep. Geol. Expl. for 1877–8, issued 1878, p. 135.

opinion, for the following reasons among others, that it belongs to the Myalinid genus *Aphanaia*,[1] de Kon., two species of which have been described from the Permo-Carboniferous of Australia :—

1. The type-specimens of the genus described by de Koninck were only casts, and consequently, as he remarks, the structure of the shell could not be ascertained. However, I obtained during the British Association excursion to the Maitland Coalfield in 1914, a specimen of *Aphanaia* cf. *Mitchelli*, from the lower marine beds of Harpers Hill, New South Wales. This specimen has the two valves in apposition, and is damaged, but part of the hinge and portions of the shell remain. The shell is prismatic in structure as it is in the case of the New Zealand fossil, and is made up of rows of upright prisms standing at right angles to the surface of the valves just as is the case in *Pinna* or *Inoceramus*.

2. The shape of the shell agrees with that of *Aphanaia*. The beaks of *Aphanaia* are anterior or terminal, and in one species are described as recurved. The hinge-line is straight or slightly bent and makes practically a right angle with the anterior margin of the shell, and there is no trace of an anterior ear. These features apply equally well to the New Zealand fossil.

The fact of de Koninck's original specimens being casts makes a close comparison a matter of some uncertainty, but apart from this the only thing which would cause me to hesitate in this attribution is that I have not been able to see the muscle-scars in the New Zealand shell. These in the Australian forms are said to be very large and pronounced, but the shells I collected at Wooded Peak are so crushed and fractured that the muscle impressions seem to have become obliterated. Only the harder and thicker region of the beaks remains more or less unbroken in the rock; the rest of the large and thin shell is crushed into small pieces, which, however, are not displaced to any extent.

I only found the separated valves at Wooded Peak, but obtained specimens from which I was able to make gutta-percha squeezes of the beak and hinge area of both right and left valves. Among the specimens which Mr. McKay collected, however, there is one which has the apex of the opposite valve in position, but I cannot say if the two valves were equal in size or not. The largest specimen I collected measures 170 mm. long and 95 mm. high. The beaks are rounded or boss-like, are nearly or quite terminal, recurved so as to face one another and stand straight above the anterior end of the hinge-line. The hinge area is broad and long, and is marked by shallow parallel longitudinal grooves separated by almost equally wide ridges.[2] The hinge-line forms an obtuse rounded angle with the posterior part of the shell, but a right angle with the anterior margin. The anterior portion of both valves in front of and below the beaks is folded inwards, and there appears to be a retreat of

[1] *Descriptions of the Palæozoic Fossils of New South Wales*, Eng. trans. (Mem. Geol. Surv. N.S.W.), Palæontology, No. 6, 1898, p. 238, pl. xxi, figs. 5, 6.

[2] This structure is, of course, quite different from that of *Inoceramus*, which has a row of vertical ligament pits on the area.

the margin so that when the two valves were together a byssal opening was produced. The surface is ornamented with a series of broad and very irregular concentric furrows and ripples.

The New Zealand specimens [1] are hardly sufficiently well preserved to justify a specific determination, but they seem to agree in most of their features with *Aphanaia Mitchelli*, F. McCoy sp., of the Upper Marine Permo-Carboniferous of various localities in New South Wales. The larger species, *A. gigantea*, de Kon., seems to differ in the boat-like shape of the larger valve and the greater obliquity of the hinge-line.

Platyschisma sp. (Pl. V, Fig. 9.)

The shell has a depressed spire and consists of four or possibly five whorls, which are smooth and rounded and increase rapidly in size. The last one is rather angular below, and the shell structure is fibrous. Owing to its poor state of preservation the growth-lines can scarcely be detected, neither could the umbilicus be clearly seen, but after examining the fragments of another specimen I think that there was a shallow umbilicus. Both in outward shape and in the fibrous structure this shell has every appearance of identity with *Platyschisma* of the Permo-Carboniferous marine beds of New South Wales, and seems to agree more closely with *P. rotunda*,[2] Eth., than with the more common *P. oculus*, Sow.

Locality.—Maitai Limestone, upper end of the Wairoa Gorge, in the side of the stream where the Roding joins the Wairoa River. The figured specimen was collected by Dr. Thomson. I found another close to the first one, but in a still poorer state of preservation.

Pleurotomaria or *Mourlonia* sp. (Pl. V, Fig. 10.)

A piece of limestone full of fragments of the prismatic bivalve shows on its weathered surface the outline of a small Gasteropod having four keeled whorls. The keel passes round the middle of the last whorl and lies above the suture in the penultimate whorl. The shell is weathered away, but in outline suggests a small *Mourlonia*.

Various small *Pleurotomariæ* are recorded from the Permo-Carboniferous of Australia and the Salt Range, but none seem quite so strongly keeled as the present form.

Strophalosia sp. (Pl. V, Figs. 4, 5.)

Hector records *Productus brachythærus* among the fossils obtained from the Maitai Limestone, but on examining the specimens

[1] I may here remark that in consequence of the occurrence of annelid-like tubes in the Maitai Limestone similar to those in the Mt. Torlesse beds and in the Yakutat slates of Alaska I suspected that the genus *Inoceramya*, Ulrich, from the latter beds might be similar to the New Zealand shell. But on looking up the description of this shell in the report of the Harriman Alaska Expedition, I found that it is quite different and possesses a series of vertical ligamentary pits and is undoubtedly closely related to *Inoceramus*. The Yakutat slates seem to be of Liassic age.

[2] Jack & Etheridge, *Geology and Palæontology of Queensland*, 1892, p. 286, pl. xv, fig. 6.

belonging to the Survey upon which his identification must have been based I see that they are really *Strophalosia.* The narrow area in both dorsal and ventral valves as well as the dental sockets in the dorsal valve are clearly apparent, and there is a large and prominent cardinal process.

The specimens are too imperfect to make any sure specific determination. In one specimen, Fig. 5, the shell is rather wider than long. The dorsal and ventral valves are strongly concavo-convex, and the dorsal valve has a rather foliaceous surface and the spines are short and curved. I have some *Strophalosias* from the Upper Marine Permo-Carboniferous of Maria Island, Tasmania, which rather resemble the New Zealand form. Taking into consideration the concavity of the dorsal valve and other features, the only described Australian form which it resembles in these respects is *S. Gerardi*, King, an Indian species which Etheridge records from various localities in Queensland and Tasmania.[1] King's figures of this Himalayan form are very like one of the New Zealand examples, Fig. 5.

Locality.—Maitai Limestone, Wairoa Gorge. I saw many sections of *Strophalosia* in the limestone near Martin's Saw-mill.

Rhynchonella (?*pugnax*) cf. *pleurodon*, Phill. (Pl. V, Figs. 6–8.)

Several casts of a small Rhynchonellid were obtained from the decalcified portions of the Maitai Limestone, from which I made gutta-percha squeezes. The beak is pointed, rather prominent, and slightly bent over, and has a well-marked triangular area. There are eleven or twelve ribs on the dorsal valve, which commence at the apex; the middle four or five ribs are straight, but the lateral ones are slightly curved, and the intervening furrows are deep and angular. The mesial ventral sinus and dorsal fold are only very slightly indicated. It is impossible to see anything of the internal structure.

This form agrees very closely in outward appearance with the above species, and is comparable with a specimen figured by Davidson (pl. xxiii, fig. 11), but is less alate and has a rather more prominent beak. It also resembles, except for the slight differences mentioned, an Australian Permo-Carboniferous specimen figured by Koninck.[2]

Martinia (*Martiniopsis* ?) *subradiata*, G. Sow. (Pl. V, Fig. 3.)

Hector recorded *Spirifer glaber* from Maitai Limestone, but I did not see the specimen upon which his identification was founded. However, I collected a single ventral valve of a smooth Spirifer which exactly resembles externally the ventral valves of specimens that I obtained from the Upper Marine Permo-Carboniferous of Branxton and Gerringong in New South Wales. The median sinus is broad and shallow, and is continued to the apex. The rest of the shell is rounded and has a rather foliaceous surface with two or three very faint rounded lateral ribs. The hinge-line is considerably less than the width of the shell.

[1] Jack & Etheridge, *Geology and Palæontology of Queensland*, 1892, p. 260.
[2] *Palæozoic Fossils of New South Wales*, p. 170, pl. ix, fig. 4.

It is impossible to remove the hard rock to see if the large and thick hinge-teeth and dental plates are present as they are in the Australian equivalents of *Spirifer glaber*, and so the absolute identity of the New Zealand with the Australian forms cannot be demonstrated.

Waagen suggested that the Australian forms of *Spirifer glaber* might belong to his genus *Martiniopsis*,[1] and this supposition is followed by Etheridge[2] apparently on the strength of Waagen's remarks. I am very doubtful whether these forms are sufficiently akin to Waagen's Salt Range genus to justify us in calling them *Martiniopsis*, in which the dental and septal plates are long and narrow and do not seem to be accompanied by a shelly infilling of the beak region. The ribbed Spirifers in the Australian Permo-Carboniferous and the New Zealand form of *Spirifer bisulcatus* are also similarly thickened in the beak of the ventral valve. Many phyla of Brachiopods develop excess of shelly matter towards the end of their existence, and it must be remembered that the Australian Permo-Carboniferous marine bands are probably of Artinskian age and very much younger than the English and Belgian Visean Lower Carboniferous.

Locality.—Maitai Limestone, junction of Wairoa and Roding Rivers.

Spirifer cf. *bisulcatus*, J. Sow. (Pl. V, Figs. 1, 2.)

Only one species of ribbed Spirifer seems to occur in the Maitai Limestone, and in outward appearance it agrees with *S. bisulcatus* as Hector originally identified it. It does not lend itself to a very close comparison with any of Davidson's figures, but strongly resembles an Australian specimen figured by de Koninck.[3]

The hinge-line is the greatest width of the shell. In the ventral valve the median sinus is continued to the apex, and is broad and shallow, and merges gradually into the rest of the shell. The ribs are closely set, narrow, rounded, equally spaced, and are similarly developed on the furrow as they are on the rest of the shell. I have no specimens which show clearly the exterior of the dorsal valve.

The interior of the ventral valve is much thickened posteriorly by deposition of shelly matter, but the dorsal valve does not seem to be thickened. The dental plates in the ventral valve are strong and heavy, and the space between them and the area is much thickened. The hinge-teeth correspond to wide and deep sockets in the dorsal valve. The thickening of the ventral valve makes it appear that the Australasian forms bear the same relation to the Northern *S. bisulcatus* as the so-called *Martiniopsis subradiata* does to the European lower Carboniferous *Spirifer glaber*, and that the similarity in exterior ornamentation does not denote specific identity.

Zaphrentis sp. (Pl. IV, Figs. 5–7.)

A selection of the few corals from the Maitai Limestone in the collection of the New Zealand Survey was sent to Dr. A. Vaughan

[1] "Salt Range Fossils": 1, *Productus* Limestone Fossils: Pal. Ind., ser. XIII, vol. iv, fasc. 2, p. 525, 1883.

[2] *Palæontology and Geology of Queensland*, 1892, p. 237.

[3] *Palæozoic Fossils of New South Wales*, pl. xiv, fig. 5c.

some years ago. No report on them has appeared, and as a result of his death the specimens cannot now apparently be traced. However, I found a specimen still remaining in the collection, Dr. Thomson found another in the Maitai Limestone, and I collected a third quite satisfactorily preserved specimen showing the sharp rim of the calyx and other features. All that I have seen are forms of *Zaphrentis*.

The specimen I collected (Fig. 7) must have measured about 55 mm. in length. The breadth at the top was about 25 mm. and the depth of the calyx 16 mm. The corallum is turbinate and almost circular in section, and the edges of the calyx are sharp. A section made slightly below the calyx shows that the fossula reaches slightly beyond the centre, and there are about forty-two septa, which are slightly sinuous and do not all reach the centre. The septa are about equally thick and maintain this thickness in their whole length. The outer ends fuse to form a quite thick thecal wall. The fossula is divided by a septum to about half its length from the outer wall. Three or four thin irregularly spaced dissepiments are seen joining each pair of septa.

This coral rather resembles *Z. Gregoryana*, de Kon.,[1] which occurs in the Permo-Carboniferous of Jervis Bay, N.S.W., but in that form the septa number thirty-six and are stated to be thicker at the outside than at the inside.

Another coral (Figs. 5, 6) is more oval in section. The septa number about 68 or 70, and are irregularly sinuous and wavy and are more or less regularly and alternately thick and thin. The septa all reach the fossula, which extends to slightly beyond the centre, and is divided along its whole length by a thin median septum, with a shorter but equally thin lateral septum on either side. The septal ends fuse to form a fairly thick outer wall, which, however, is partly eroded.

Locality.—Both these corals occurred in the Maitai Limestone at the junction of the Wairoa and Roding Rivers.

[Since writing the above I have received the following note on the coral sections from Mr. Stanley Smith, D.Sc., F.G.S., who has kindly examined the specimens for me:—"Both specimens may be safely assigned to the genus *Zaphrentis*, although it would not be wise to compare them with any British species, especially since they have undergone considerable mineral change. The specimens appear to represent two distinct species rather than two growth stages of a single species. The larger specimen (Fig. 7) displays a large and conspicuous cardinal fossula, the septa are not crowded, and there is a well-developed dissepimental zone. In the smaller specimen (Fig. 5) the fossula is distinct but not prominent, the septa are numerous and crowded, and there is no dissepimental zone. The latter may have perished or may be undeveloped at the stage growth represented by the section. In the two sections only the major septa are developed; in Fig. 5 the septa are dilated and split by mineralization, so that the first impression is that of thin septa alternately long and short; the shorter line is the medial 'dark line' of the septa."—S. S.]

[1] *Palæozoic Fossils of New South Wales*, pl. v, fig. 7.

Serpulites (?) sp. (Pl. V, Fig. 11*a*, *b*.)

A fragment, 5 mm. long, of a tubular organism, now siliceous, but probably originally calcareous. It is almost circular in section at one end, where it measures 5 mm. in diameter, but slightly oval at the other. Its outer surface seems to be rather rough. This organism suggests the tubular structures called *Torlessia McKayi*, Bather,[1] which occur in the Mt. Torlesse Annelid beds, and which most New Zealand geologists consider the highest member of the Maitai Series.

It also suggests *Serpulites Warthi*,[2] Waagen, which is said to be very common fossil in the Lower Speckled Sandstone and the glacial Boulder Beds of the Salt Range, the fauna of which is equivalent to that of the marine Permo-Carboniferous of Australia and the Maitai fauna of New Zealand.

Locality.—Maitai Limestone, junction of Wairoa and Roding Rivers, Wairoa Gorge.

All the ten genera and species I have described, with the exception of the comparatively unimportant Serpulites, occur in the marine Permo-Carboniferous of New South Wales.

The evidence, therefore, of the fossils of the Maitai rocks, few as they are, is overwhelmingly in favour of a correlation of these beds with the marine Permo-Carboniferous of New South Wales and Tasmania.

The absence of certain familiar fossils of Australia and the Salt Range, such as *Eurydesma*, *Conularia*, *Aviculopecten*, etc., may be noticed, but their absence may be explained on geographical or bathymetrical grounds. The Boulder Bed of the Salt Range is equally wanting in some forms, but Waagen does not hesitate to correlate its fauna with that of the Permo-Carboniferous of Australia.

The Relation of New Zealand to Gondwanaland.

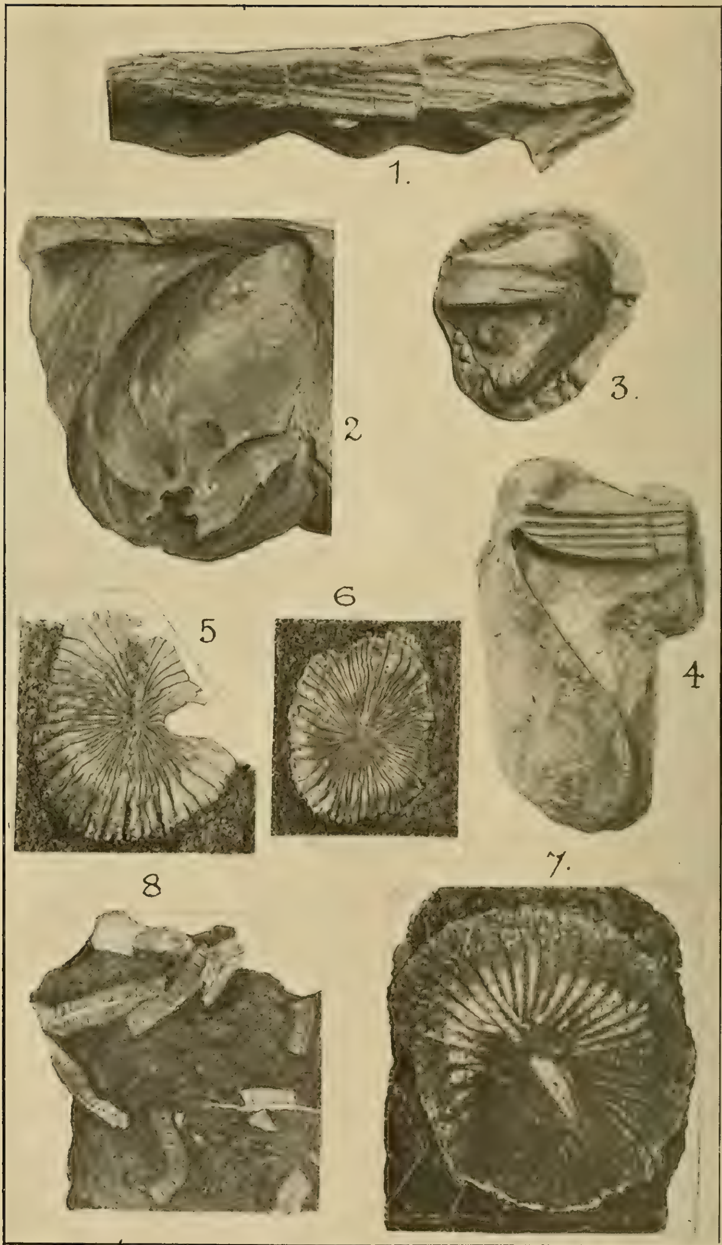
The attribution of the fossils of the Maitai Series to a Permo-Carboniferous age, equivalent to the marine bands in the Permo-Carboniferous of New South Wales and Tasmania, raises the question both of the presence or absence of a *Glossopteris* flora, and of the relations of the New Zealand area to Gondwanaland.

Mr. E. A. N. Arber[3] has shown that the flora of the Mt. Potts Beds of the Canterbury Alps, which Hector supposed to contain *Glossopteris*, is really of late Trias or Rhætic age, and the supposed *Glossopteris* is a new genus which he calls *Linguifolium*, allied to certain plants in the Rhætic of Chili. This result agrees on the

[1] "The Mount Torlesse Annelid": Geol. Mag., Dec. V, Vol. II, pp. 532–41, 1905.

[2] "Salt Range Fossils": Geological results: Pal. Ind., ser. XIII, vol. iv, pt. ii, p. 135, pl. iii, figs. 5, 6*a*, *b*, 1891.

[3] "Preliminary Note on the Fossil Plants of the Mount Potts Beds, New Zealand": Proc. Roy. Soc., B, vol. lxxxvi, pp. 344–7, 1913. Mr. Arber remarked to me in a letter that even if *Glossopteris* should be found at Mt. Potts, which is extremely improbable, it would not mean that the beds are Permo-Carboniferous, since *Glossopteris* occurs in Rhætic beds in Tonkin and China. The Mt. Potts flora is a Mesozoic one "beyond redemption".



MAITAI LAMELLIBRANCH: CORALS.

whole with my independent determination of the Kaihiku marine fauna, which is associated with the plant beds at Mt. Potts as of late Middle or early Upper Trias age.

Since no trace of *Glossopteris* or any other plant is recorded from the Maitai rocks the palæobotanical evidence is removed. Further, although several coarse conglomerates occur in the Maitai Series, nothing for which a glacial origin can seriously be claimed has been found. The Permo-Carboniferous of New Zealand differs from that of South Africa, the Salt Range, Australia, Tasmania, the Falkland Islands, South America, or other regions of Gondwanaland in the absence of glacial beds or of a *Glossopteris* flora. There is no trace in New Zealand of a non-marine plant-bearing Permo-Carboniferous series, and there seems no prospect of any turning up. The beds appear to be entirely marine, but were evidently deposited not far from some land mass of continental dimensions.

The conclusion, therefore, is that although the New Zealand area formed no actual part of Gondwanaland, it lay during the Permo-Carboniferous period not far from the shores of this or some similar great land mass which supplied the materials which build up the Maitai Series.

In no part of New Zealand has definite[1] evidence of any unconformity between the Maitai and the Trias been found, and so it is possible that uninterrupted marine conditions persisted from the Permo-Carboniferous times through the Trias and on into the Jurassic period.

EXPLANATION OF PLATES IV AND V.

(All figures natural size except where otherwise indicated.)

Plate IV.

Fig.

1.—*Aphanaia* sp., cf. *Mitchelli*, F. McCoy, sp. Hinge and area of left valve. Nat. size. Gutta-percha squeeze. Maitai Slates, Wooded Peak, near Nelson. Author's collection.

2.—Ditto. Cast of right valve of a small specimen showing the concentrically furrowed shell. Nat. size. Dun Mountain Tramway, near Nelson. New Zealand Geol. Surv. collection.

3.—Ditto. Gutta-percha squeeze of apex of a left valve. Nat. size. Maitai Slates, Wooded Peak, near Nelson. Author's collection.

4.—Ditto. Gutta-percha squeeze of apex and part of the area of a right valve. Nat. size. Maitai Slates, Wooded Peak, near Nelson. Author's collection.

5.—Section of *Zaphrentis* sp. Magnified 2 diameters. Maitai Limestone, junction of Wairoa and Roding Rivers, Wairoa Gorge. Dr. Thomson's collection.

6.—Section of the same coral cut rather lower down.

7.—Section of *Zaphrentis* sp., cf. *Gregoryana*, de Kon., cut just below the calyx. Magnified 2 diameters. Maitai Limestone, junction of Wairoa and Roding Rivers, Wairoa Gorge. Author's collection.

8.—Section of Maitai Limestone from the Wairoa Gorge with a cluster of prismatic fragments of the large bivalve *Aphanaia*. Author's collection.

[1] The reported occurrence of an unconformity between the Kaihiku and Takitimu Series in the Takitimu Ranges seems to require further investigation. Cox, Rep. Geol. Explorations, 1877–8, "Geology of the Te Anau District," p. 113.

FIG. PLATE V.

1.—*Spirifer* cf. *bisulcatus*, J. Sow. Ventral valve. ⅘ nat. size. Maitai Limestone, Martin's Saw-mill. Wairoa Gorge. New Zealand Geol. Surv. collection.

2.—Ditto. Internal cast of ventral valve in decalcified rock. Nat. size, showing the thickened interior of the ventral valve and dental plates. Same locality. New Zealand Geol. Surv. collection.

3.—*Martinia* (*Martiniopsis* ?) *subradiata*, G. Sow. Ventral valve. Nat. size. Maitai Limestone, junction of Wairoa and Roding Rivers, Wairoa Gorge. Author's collection.

4.—*Strophalosia* sp. Interior of dorsal and beak of ventral valve. Nat. size. Maitai Limestone, Martin's Saw-mill, Wairoa Gorge. New Zealand Geol. Surv. collection.

5.—*Strophalosia* sp., cf. *Gerardi*, King. Gutta-percha squeeze of exterior of dorsal valve, ventral beak, area, etc. Nat. size. Same locality, in decalcified rock. New Zealand Geol. Surv. collection.

6–8.—*Rhynchonella* (*pugnax*) cf. *pleurodon*, Phill. Gutta-percha squeezes of parts of dorsal and ventral valves, area, etc. Nat. size. From decalcified limestone at Martin's Saw-mill. Wairoa Gorge.

9.—*Platyschisma* sp., cf. *rotunda*, Eth. Nat. size. Maitai Limestone, junction of Wairoa and Roding Rivers, Wairoa Gorge. Dr. Thomson's collection.

10.—*Pleurotomaria* (?) or *Mourlonia* sp. × 4.

11*a*, *b*.—*Serpulites* (?) sp. Maitai Limestone. *a*, section; *b*, side-view of tube. × 3.

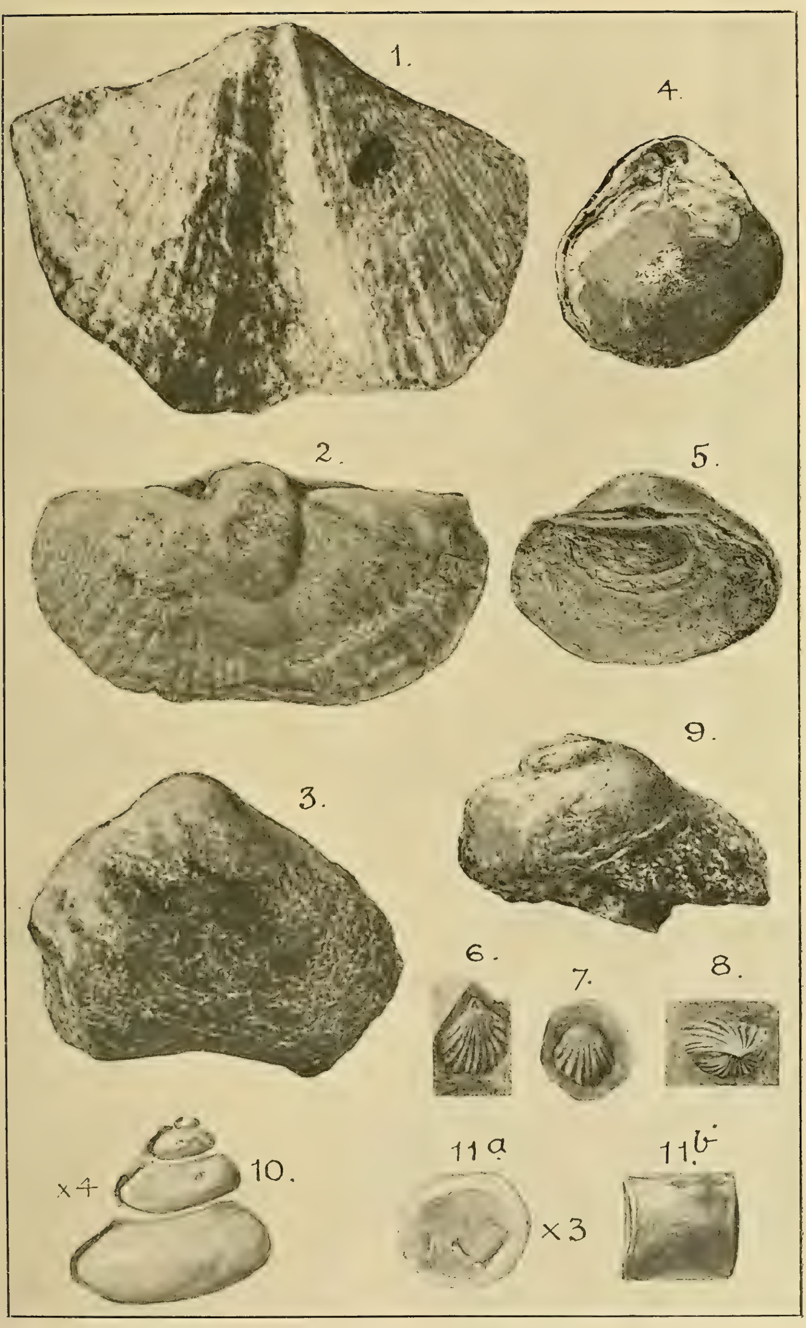
III.—THE RHYTHMIC DEPOSITION OF FLINT.

By Professor GRENVILLE A. J. COLE, M.R.I.A., F.G.S., Royal College of Science, Dublin.

MR. G. W. BULMAN, in an essay on "Chalk Flints and the Age of the Earth",[1] states that Professor Owen regarded the layers of flint in chalk as "the remains of *successive* crops of sponges which grew again and again according to *some periodic law*". Mr. Bulman then observes that the only periods affecting rock-formation are annual, and he suggests that sponge-growth might be rapid during the summer months and that free-swimming reproductive spores might be liberated towards winter, the old sponges then dying off. This implies that the water at the depths in which the sponges lived in our Cretaceous seas was responsive to climatic change, and that the sponges were equally responsive. The suggestion breaks down, however, on another ground, when its author points out that it demands the deposition of 3 or 4 feet of chalk in a year, so that the whole of the English strata above the Albian might have accumulated in about four centuries. Mr. Bulman thereupon remains hesitant and enquiring.

In the extensive literature on flint-formation, there are probably many suggestions to account for rhythmic deposition. The matter appears, however, to be generally passed over in our textbooks. Sir C. Lyell's reference[2] to changes in marine currents, "favouring at one time a supply in the same area of siliceous, and at another of calcareous matter in excess, giving rise in the one case to a preponderance of Globigerinæ, and in the other of Diatomaceæ," seems

[1] *Science Progress*, No. 41, p. 154, July, 1916.
[2] *The Students' Elements of Geology*, p. 265: 1871.



MAITAI BRACHIOPODS: GASTEROPODS, ETC.

a very casual way of dealing with the difficulties of the problem. G. C. Wallich [1] in 1879 anticipated Mr. Bulman's suggestion of the periodic destruction of sponge life; but his hypothesis allows of a prolonged time-interval between the formation of successive layers. His paper is not systematic and does not provide easy reading; but the following argument may be picked out from it and pieced together. Ordinary Globigerina-ooze contains but little silica, like the beds of chalk between the flint-zones; oceanic dredgings, however, show larger amounts of silica, because they represent only the superficial layer of the deep-sea ooze. This layer contains a large amount of protoplasm floated up from the foraminifera, including Globigerinæ, that multiply on the sea-floor. Sponges flourish in this layer and add the silica of their spicules to it; but a great addition of silica is made by the raining down of radiolarian skeletons from surface-waters. The radiolaria live only at the surface, and their remains are caught in the protoplasmic layer, which thus becomes more and more highly charged with silica. The protoplasmic masses [2] "will become, if not supersaturated with silica, at all events so highly charged with it in a now colloid state more and more closely approaching coagulation, as eventually to asphyxiate—so to speak—the very organisms which have produced them".

Owing, no doubt, to the paucity of thin sections of flint at the date at which he wrote, Wallich shows no appreciation of the fact that the silica of flints replaces calcareous organisms and that a flint-zone may prove to be a pseudomorph of a consolidating bed and not a record of a differentiated layer on its surface. In his reply to the discussion (p. 92), he somewhat vitiates his previous argument by introducing a new point, the attraction by sponges of colloidal silica "which existed at the surface of the mud". The paper, however, is clearly an attempt to meet the question of rhythmic deposition. In recent years, however, zonal crystallization has become realized through a number of attractive experiments, notably those of R. E. Liesegang, and a new field of thought has opened in regard to our familiar flints.

Mr. Bulman,[3] after laying stress upon the annual repetition of sponge-deposits, quotes some correspondence with myself in regard to Liesegang's work, and urges that the prevalence of sponges along particular horizons would in any case be necessary to account for the localization of the silica. He concludes, "I make these remarks with the reservation that there *may be* in Liesegang's work, and in Professor Cole's suggestion, details of which I am not aware, and which might render them a more complete explanation of the *lines of flint* than they appear to be."

Since Liesegang's *Geologische Diffusionen* (Dresden, 1913) is not widely accessible in our Islands, it may be well to mention how the question of flint-horizons is introduced in that highly suggestive and stimulating work.

One of the fundamental propositions governing the deposition of

[1] "A Contribution to the Physical History of the Cretaceous Flints": Quart. Journ. Geol. Soc. London, vol. xxxvi, p. 68: 1880.

[2] Op. cit., p. 82.

[3] Op. cit., *Science Progress*, No. 41, p. 156.

concretionary layers is the fact that a crystal growing in a solution is surrounded by a zone of less than average concentration. The crystal-growth impoverishes the solution round about it. If new material is diffusing into the solution, the impoverished zone becomes again enriched; additions are made to the crystal, and a new unsaturated zone is formed around it.

Where a jelly that has absorbed ammonium bichromate is used as a medium for the diffusion of a solution of silver nitrate, silver chromate is formed. At a certain concentration Ostwald's metastable boundary is attained, and crystallization of the silver chromate occurs, even if there are no nuclei to serve as centres of deposition. Each crystal thus formed is surrounded by an impoverished zone; but the arrival of fresh material again leads to enrichment, and the crystals grow until they form a band within the jelly at the surface where the necessary concentration is produced.

The silver chromate in this experiment arises from reaction with material on the far side of the band, and the distance through which such material moves to reach the crystalline nuclei is limited. An impoverished layer thus arises beyond that of deposition, and the silver nitrate diffusing through the layer of deposition has to progress for some distance before the metastable boundary is again attained. Successive zones are thus built up, with intervals which represent regions of weaker concentration of silver chromate.

As we follow out Liesegang's application of these phenomena to the explanation of zonal structures in agates, in concretions, and in massive rocks, we come with delight upon his brief but illuminating reference (p. 126) to the rhythmic layers of flint in limestone. He pictures a solution of silica or of a silicate spreading through a fairly uniform sediment. Or, in the case of the chalk, the silica may have been at first distributed with approximate uniformity, and then became affected by a progressive "one-sided" precipitation. It is pointed out that drying of the rock, due to elevation, may play its part together with the processes of diffusion.

We may venture to expand this conception in relation to the familiar flint-layers in the chalk. Layer-structure may be reasonably expected in a rock containing concretions, if a solution has moved through the mass from above or from below, or from one side to the other. The movement, in a drying sediment, may be upwards; or the solvent water may drain downwards when the mass is uplifted above the sea. Since the consolidation of the rock usually precedes folding and fracturing processes, it must be held to take place in geological time with some rapidity. Mountain-building processes, as we know, may overtake those of consolidation, and firm rock-masses may be forced into yielding sands and muds of younger age. But the chances are in favour of the occurrence of concretionary deposition while the sediment remains practically undisturbed. The concretions will develop along planes of bedding, because the solution to which they are due has moved perpendicularly to these planes.

This theory is directly opposed to that which many of us have enunciated in our teaching work, when we regarded the concretions as formed along the bedding-planes because these planes provided the easiest direction of movement for permeating waters. The geological importance of the phenomena of diffusion was set before us by H. J. Johnston-Lavis[1] as far back as 1894, and the rhythmic deposition of silicates in limestone was described by him in association with J. W. Gregory[2] in the same year. These observations have of late received full recognition, and may well prepare us to regard concretionary zones in rocks as lying perpendicular to the direction of movement of solutions.

Cracks may arise in which the materials that elsewhere form concretions may become deposited as the solution concentrates through evaporation; but the main surfaces of deposition are likely to be parallel with the bedding-planes of the sediment in which the concretionary growth occurs.[3]

In sandstones concretions usually imply a mere cementing process, or the local chemical replacement of a material already present as a cement. Cases are now known to us where iron-ores form pseudomorphs of quartz-grains; but the typical examples of concretionary growth by pseudomorphic substitution occur in limestones. Here, of course, there must be a diffusion in two directions; the calcium carbonate must pass out while something is being precipitated in its place. In the case of flints, it has often been supposed that layers more rich in the siliceous spicules of sponges or radiolarians attracted additional silica derived from the solution of similar skeletons in other portions of the rock. While it seemed improbable that the lumps of flint which replace the limestone around casts of siliceous skeletons, or which, in other cases, include mere scattered spicules, owed the whole of their silica to the nucleus around which they grew, it was thought that abundant nuclei were requisite. On the hypothesis of rhythmic deposition, however, the difficulty raised by Dr. Wallich and Mr. Bulman as to a periodic abundance of sponges disappears.

The residual skeletons and spicules in a zone of rhythmic deposition may have acted as nuclei and may thus have aided flint-formation; but for the most part they are preserved merely as casts, like those in the adjoining parts of the chalk that are devoid of flints. A very general solution of the hard parts of diatoms, radiolarians, and siliceous sponges appears to have taken place in the body of the chalk, and the traces of sponges within the flints represent so much material added to the invading solution, until, by exchange with calcium carbonate, silica began to be deposited.

We may note that Mr. Bulman's suggestion that animal matter

[1] "The Causes of Variation in the Composition of Igneous Rocks": *Natural Science*, vol. iv, p. 139: 1894.

[2] "Eozoönal Structure of the Ejected Blocks of Monte Somma," Sci. Trans. R. Dublin Soc., vol. v, p. 264: 1894.

[3] The concentric rings of flint in the chalk of Cromer, described by Clement Reid on p. 4 of *The Geology of the Country around Cromer* (Mem. Geol. Surv.: 1882), seem a case of diffusion of silica outwards from certain centres in a stratum about a foot in thickness. One of these rings has a longer diameter of 15 feet; others are perfect circles 9 feet in diameter. The two concentric circles figured in the memoir certainly suggest rhythmic deposition. It would be interesting to know what physical character of the beds above and below has prevented the rings from developing into spherical shells.

may start the segregation is hardly sustained by the examples that he brings forward. The "tests of sea-urchins and bivalve shells" are not very often "converted into flint". Casts of their interiors are common enough, and flint often encloses the calcareous tests. The infilling of calcareous ooze has become silicified, like the chalk surrounding the remains. The test, especially when formed of calcite, has resisted pseudomorphism.

There is something inspiring in the conception of a thousand feet of chalk, with an area of some thousands of square miles, acting as a medium for waters which rearrange the silica left by organisms throughout its mass. It remains to be seen if field-observations raise any serious objections to this view. If we could find limestones contorted at so early a stage that the zonal silicification set in at a later date, the zones of flint should be independent of the planes of stratification.[1] But flints seem, as I have previously remarked, to belong to the first stages of consolidation, when the waters are being drawn up or sink down vertically through the mass. These waters group the silica as they diffuse, and they emerge or drain off elsewhere in the form of calcareous springs.

Though flint in other limestones is often spoken of as chert, our considerations must be by no means limited to the siliceous nodules in the Chalk. Reversing the opinions that we formerly held, we may see in the rhythmic deposition of flint an indication that the silica was originally evenly distributed in the mass. When layers of varying texture and mineral composition are present, they check continuous diffusion. The more uniform conditions in the chalk of Upper Cretaceous age have no doubt given us a classic example; but nodular layers, and even regularly surfaced beds of flint, are known to most workers in the Carboniferous Limestone. A fine instance occurs in the steeply dipping strata in a quarry at Ballintemple, east of the city of Cork. The Portland Beds of the south of England, and the white Cainozoic limestones of the Paris Basin, also furnish examples in easily accessible lands.

IV.—Geology at the Seat of War.[2]

By Aubrey Strahan, Sc.D. (Camb.), Hon. LL.D. Toronto, F.R.S., V.P.G.S.

At a time when the resources of every branch of science are being devoted to the furtherance of the War, it is not inappropriate to consider in what way geological research is being turned to account. At first sight it might appear that the work of the stratigraphical geologist, the palæontologist, or the petrographer might be of domestic and academic interest, but would be unlikely to influence the course of a worldwide war. Such researches have received a respectful

[1] The only reference with which I am acquainted as to the relation of flint-zones to earth-movement is the remark by W. Hudleston in the discussion on Wallich's paper that flints are absent from 'flat' beds of Coral Rag at North Grimston, but are present where the beds are bent (Quart. Journ. Geol. Soc. London, vol. xxxvi, p. 92). This interesting observation deserves, and may have received, further investigation.

[2] Presidential Address to the Vesey Club, December 12, 1916 (Abstract).

toleration in this country, but have been regarded as a luxury, to be abandoned first among luxuries in time of stress. I venture to hope, however, that it will not be so necessary in the future as it has been in the past to expend energy in urging the claims of science. In the foundation of the Imperial Trust for Scientific Research we may recognize that at least one good result has arisen from the calamity of war.

The Germans have been active in their application of geology at the Front, but that they have been more active than ourselves must not be assumed from the fact that I speak more freely of their proceedings than of our own. The amount of German literature which has reached me since the outbreak of the War is limited, but it suffices to show that a number of treatises on War Geology has been published, and from one of these I extract some significant passages. One author, writing in December, 1915, remarks that first and foremost they (the Germans) have really begun, in different parts of the Front, to make geologists a part of the Army organization. A staff of geologists has been created and placed under the direction of a Professor of the University of Greifswald for one of the divisions of the Western Front, and an extension of duties arranged for when their present task is finished. Among the subjects mentioned as requiring geological advice are the laying of field railways, the provision of water in co-operation with bacteriologists, the examination of marsh-lands, the finding of road-metal, and the guarding against landslides, which may be brought about by gunfire. Hints are given, too, that much greater use has been made of geological maps for military purposes than can be made known now. In fact, I gather from this author, who is himself a professor of palæontology, that a sufficient and intelligent use of geologists would go far to win the War. He admits, however, that an individual geologist may not be infallible, and he acknowledges that in attack or retreat the first line cannot wait for the geologist's advice. He proceeds to recommend that full advantage should be taken now of examining the innumerable artificial openings which have been made, and gaining such a knowledge of the ground of our neighbours as may be desirable for military purposes. "For," he continues, "the peace will not be an everlasting peace. Who can hope for that? We, whose country has so often been invaded, must therefore prepare to defend ourselves, and as the new battles may very likely be fought on the ground on which our armies are now fighting, our descendants would be justified in reproaching us if we were so short-sighted as not to avail ourselves of the present favourable opportunity of examining the geological character of the field of battle." I invite your attention to the fact that preparation for another war is suggested while the present war is at its height, and that protection against further invasion of Germany is to be obtained by studying the geology of the territories of her neighbours.

In connexion with the operations on the Western Front a comparison of the geology with that of the South of England acquires a special interest. The severance of England from the Continent is, geologically speaking, a recent geographical incident. That the chalk escarpments of the North and South Downs are continued in the chalk escarpments which overlook Boulogne is obvious, and that the subdivisions of the Tertiary strata with which we are familiar in the London and Hampshire Basins are recognizable in the North of France and in Belgium is well known. Not only so, but the scenery characteristic of each formation is reproduced with fidelity.

In one respect only the Continental deposits differ materially from those of our home counties. Over wide tracts there has been distributed, up hill and down dale, a fine yellow loam, the *limon* of Belgian geologists, which is doubtfully, if at all, recognizable in England. The thickness varies from 100 feet in the valleys to a mere trace on the flanks of the higher hills, where it shades into hill-talus, but the material is generally spread as a mantle over the country regardless of elevation. This is the deposit with which our men are generally in contact in trenches and the smaller dug-outs, and which is in evidence on the clothes of those returning from the Front.

Much has been written on the origin of the *limon*. It has not the character of a stratified subaqueous deposit, and its fossils include no marine and but few freshwater shells. Land shells, however, are embedded in it, with the bones of various herbivorous and carnivorous mammals. Judged by all these characters, its uniformity of grain, its disregard of level, and its fossil contents, it has been attributed in the main to subaerial agencies. It is in fact a dust, distributed by the wind and retained wherever it settles on ground thickly clothed with vegetation. Like the loess, with which it has many characters in common, it appears to have been formed in countries which suffer from extreme alternations of dry and wet seasons.

In dry weather the *limon* readily returns to a condition of dust; in wet weather it forms a mud unlimited in quantity and obstructiveness. But as a material in which trenches and dug-outs can be excavated with the minimum of labour it seems to have found some use. Under the *limon* and for the most part visible only by means of wells or boreholes, lie the Tertiary and Cretaceous formations.

The southern margin of the Tertiary tract, which includes the London and the Belgian Basins, runs near Basingstoke, Guildford, and Canterbury to the coast near Deal. It strikes the French coast south of Calais, and passes thence by Béthune, Mons, Namur, and Liège. As far as Béthune the margin lies within the lines of the Allies as at present situated, but thence southwards it passes into ground occupied by the enemy.

Along parts of the margin the strata, both the Tertiary beds and the Chalk below them, are tilted up at a high angle, as for example near Guildford, and in such a case the Chalk projects in a ridge, typically illustrated in the Hogs Back. But on the Continent the Chalk emerges at a gentle angle, and the passage from rolling Chalk downs to low undulating plains of Tertiary beds is gradual. Indeed, outlying patches of Tertiary beds, from a few acres to a few square miles in area, are scattered abundantly over the higher parts of the downs. Geologically this tract is comparable to many parts of Hertfordshire, Buckinghamshire, Berkshire, Surrey, and Kent, and the close correspondence of the strata in detail gives a peculiar interest to a study of these parts of England at the present time.

In the London Basin we recognize three groups in the lower Tertiaries, and in the Hampshire Basin the same three groups with other higher Tertiary strata which have been removed from the London area by denudation. The lowest group, resting directly upon the Chalk, is known as the Reading Beds and Thanet Sands with pebble beds. The thickness of the group amounts to 100 feet in places. At its base lies a layer of unworn chalk-flints coated with a green silicate of iron, and interbedded in the sands are clays, often of a vivid red colour.

These characters are reproduced in the *Landenien* of Belgium. The interbedded clay is known as the *Argile de Louvil.*

The Reading Beds pass below the London Clay, and under suitable circumstances the water in them is held down under pressure by that impervious covering. In such cases, when a hole is bored through the clay, the water rises from the sand and overflows at the surface. This used to be the case years ago in parts of London, and well-borers sometimes found themselves in unexpected possession of an uncontrollable fountain which flooded their own and their neighbours' premises. On the Continent an artesian supply is still available in suitable conditions within the margin of the Tertiary basin. The water, however, is potable only near the margin; in the inner parts of the basin, far away from the outer edge, it is too heavily loaded with mineral matter to be usable.

The London Clay, which comes next above the Thanet Sand, has a thickness of 400–450 feet. It corresponds in character, thickness, and fossils to the *Argile de Flandres*, or the *Yprésien* of Belgian geologists, except that in Belgium it consists in the upper part of alternating bands of sand and clay. London Clay has its uses. Almost the whole of the system of tube-railways under London has been constructed in this watertight material. The earlier underground railways, the sewers, and other works were situated nearer the surface, and encountered large quantities of water in the superficial gravels; the tubes were protected by clay above and below, except in a few exceptional localities.

The Bagshot Sands come next above the London Clay. These attain a thickness of approximately 1,000 feet in Hampshire, but in the London Basin have been for the most part denuded away. Parts of them, however, still remain near Aldershot, Bagshot, and Ascot and on the tops of Highgate and Hampstead Hills. Wherever they exist they make their presence apparent by a characteristic scenery of heath or pine forest. In Belgium they are represented by the *Paniselien* and *Bruxellien* Sands, and there also they produce a type of country which is in strong contrast with that produced by the Yprésien Clay. The conspicuous hill on which Cassel stands is composed in the main of Paniselien Sand, though it includes some later formations on its summit. Eastwards, as the Belgian Tertiary basin is approached, the Paniselien Sand comes on in greater force. It forms the bold range of hills which surround Ypres on its southern and eastern sides, and which includes the site of the famous Hill 60.

The Paniselien and Bruxellien Sands absorb a large proportion of the rain that falls upon them, and give out the water as springs at their base, where they rest upon impervious clays or along any interbedded clay-band. Bailleul draws, or used to draw, a part of its supply from a spring of this character in the side of Mount Noir, one of the hills south of Ypres. Ypres was supplied by similar springs at Dickebusch and Zillebeck, but the gathering-ground of the springs includes the scene of some of the most murderous fighting of the war, and it may well be questioned whether water drawn from such an area can be usable. In other parts of Belgium a system, which is rarely seen in Britain, of driving tunnels under the larger tracts of such sands and collecting the water by branching galleries, has been adopted. Brussels is partly supplied in this way.

The Chalk of the South-East of England includes three subdivisions of more or less distinctive lithological characters. The Upper Chalk is a massive type of chalk set with nodules or rows of nodules of flint. This subdivision ranges to upwards of 600 feet in thickness and forms the upper and bolder part of the chalk escarpments. The Middle Chalk is a thick-bedded chalk generally devoid of flints, and the Lower Chalk includes much chalk marl. The Upper Chalk is the source of water of the majority of chalk wells. The Lower Chalk, on the other hand, though it may hold much water, yields it but slowly on account of its marly and almost impervious character. For this reason the Lower Chalk has been much discussed as a suitable stratum in which to drive a tunnel from Dover to Calais. In fact, the small part of the tunnel which has been driven is situated in this subdivision.

In the North of France these subdivisions of the Chalk present much the same characters as in the South-East of England, but there extends from near Calais towards Mons an underground bar, which clearly existed in the Cretaceous sea as a ridge or at any rate an obstruction to the free circulation of currents. The Upper Chalk, though it crosses the bar, changes its character. The whole formation assumes a marly character under Flanders, and loses its value as a reliable source of good water. Herein lies the difficulty of finding water supplies in Eastern and Western Flanders. The Landenien water is often not potable, and the Chalk yields none. The Palæozoic rocks beneath yield salt water, if any, and the uplands of Paniselien Sand are too limited in area to give a sufficient supply by gallery. Under these circumstances recourse has been had to rain and canal water, rendered harmless, as believed, by chemical treatment and filtration. So keenly was the lack of good water felt that a project was on foot before the War to supply the towns of Low Belgium from a source in the Ardennes. The supply had been carried to Brussels, and its further distribution was in progress when the War broke out.

Chalk forms one of the most suitable rocks for dug-outs, provided that the excavations are not carried below the level of the underground water. It is not difficult to excavate, and yet firm enough to stand fairly well. The extensive and elaborate system of underground dwellings recently captured by our troops have been excavated in the Chalk.

For obvious reasons it would be unwise to describe in detail the problems which have arisen for solution at the Front, but it may be legitimate to remind you that tunnels, unlike wells, should be so designed as to keep clear of water, and that the best way of effecting this object is to keep the operations within the limits of a watertight formation, as was done in the case of the tube-railways. An exhaustive study of the thicknesses and inclinations of the strata, and especially of the faults or folds by which they are affected, is required for the purpose. The necessary observations are not easy to make, for the calm reflection required for the solution of a geological problem is apt to be interrupted by the attentions of the enemy. Operations are of necessity hurried and hazardous. It is well also to endeavour to realize the conditions under which our men are working in the tunnels. There is no branch of the Services, whether on the sea or under it, on the ground or in the air, in which pluck and endurance have not been manifested to a degree which would have been scarcely credible two or three years ago. No less are these qualities called for in the men who are working in the bowels of the earth, with the ever-present danger of being forestalled by the enemy and of being buried alive with no possibility of rescue.

The Secondary and Tertiary formations rest upon an undulating plane cut in the Palæozoic rocks, conveniently known as the Palæozoic floor. These ancient rocks have been thrown in the course of geological ages into the most complicated structures. Not only are they folded, but along certain belts of country they have been inverted and their newer members thrust bodily over their older members. The plane therefore cuts across rocks of many ages, ranging from Coal-measures to Cambrian or earlier. In the locating of Coal-measures among these older rocks, under the blanket of Secondary and Tertiary strata, lies the problem of extending the coal resources of the country.

The first step towards accomplishing this in the South of England was taken in Kent, where the existence of Coal-measures was anticipated on geological reckoning many years ago and proved in 1886. It was argued that the Axis of Artois, a belt characterized by intense folding and overthrusting from the south, which ranges past Liège, towards Douai and thence to the coast near Calais, must continue through the South of England, and that there might be coalfields entangled in it in England as on the Continent.

The numerous borings put down in Kent since 1886 have had the result of proving that the Coal-measures there lie in a trough in the Carboniferous Limestone, the axis of which ranges in a north-westerly direction. The dips observable in the cores are usually gentle, and there is nothing to suggest faulting or folding such as characterize the coalfields situated on the Axis of Artois.

It therefore is still a matter of doubt whether the Kent Coalfield is situated on that axis, and not to the north of it, and whether it does not compare in this respect with the coalfield of La Campine. This field was discovered in 1901, and twelve or more shafts were being sunk through the Tertiary beds and the Chalk into the Coal-measures when the War broke out. By some Continental geologists it is thought likely to be continuous with the Yorkshire Coalfield, by others with the Kent Coalfield, but attempts to follow it in a northerly direction have so far been defeated by the great thickness of Tertiary sands near Antwerp. Apart from the highly speculative question of its extension in either of the directions named, it seems to be comparable to the Kent Coalfield in its relation to the great belt of folding along which the other Belgian coalfields are situated.

V.—Note on *Plectrodus*, the Jaw of an Upper Silurian Fish.

By Arthur Smith Woodward, LL.D., F.R.S.

When fish-remains were first discovered in the Ludlow bone-bed and other horizons of the Upper Silurian series, some of the fragments were regarded as toothed jaws by Agassiz, who described them under the names of *Plectrodus mirabilis*, *P. pleiopristis*, and *Sclerodus pustuliferus*.[1] The same fossils were afterwards considered to be of Crustacean origin by M'Coy,[2] but definitely proved to be fish-remains by the microscopical examination of Harley, who pointed out that while they could not be teeth or jaws, they appeared to him to be "the posterior spines of the cephalic plate of some Cephalaspidian fish".[3] The latter view was adopted by Lankester, who treated the specimens as parts of the cornua of a small Cephalaspidian head-shield which he named *Eukeraspis pustuliferus*.[4]

Egerton[5] also described similar fossils as jaws, and among these was one specimen from the Downton Sandstone (Brit. Mus. No. 45969), which I studied some years later and considered to resemble a fish-jaw rather than a cornu of *Eukeraspis*.[6] In 1893 Rohon[7] made a microscopical examination of several fragments both from the Ludlow bone-bed and from the well-known Upper Silurian limestone in the Isle of Oesel (Baltic Sea), and concluded that while some of the specimens ascribed to *Plectrodus* and *Sclerodus* were Cephalaspidian, others were certainly not of this nature. He described the latter as exhibiting "denticles and tubercles of vasodentine, and the base not formed of true bony tissue but of a bone-like substance". In 1898 I found in the Museum of Neuchâtel three of the original specimens from the Ludlow bone-bed which were described by Agassiz (labelled "Rev. Wm. Evans, 1836"), and two of these (figured in *Siluria*, pl. iv, figs. 15, 25) appeared to me distinctly jaw-like. In 1910

[1] L. Agassiz, in Murchison's *Siluria*, 1839, p. 606, pl. iv, figs. 14–32, 60–2.
[2] *Pterygotus pustuliferus*, F. M'Coy, Quart. Journ. Geol. Soc., vol. ix, p. 14, 1853.
[3] J. Harley, "On the Ludlow Bone-Bed and its Crustacean Remains": Quart. Journ. Geol. Soc., vol. xvii, p. 544, 1861.
[4] E. Ray Lankester, *Fishes of the Old Red Sandstone*, pt. i (Pal. Soc., 1870), p. 58, pl. xiii, figs. 9–14.
[5] P. M. G. Egerton, "On some Fish-remains from the Neighbourhood of Ludlow": Quart. Journ. Geol. Soc., vol. xiii, p. 288, pl. x, figs. 2–4, 1857.
[6] A. S. Woodward, *Catalogue of Fossil Fishes in the British Museum*, pt. ii, 1891, p. 195.
[7] J. V. Rohon, "Die Obersilurischen Fische von Oesel": Mém. Acad. Imp. Sci. St. Pétersbourg [7], vol. xli, No. 5, p. 95, 1893.

Priem[1] described and discussed similar fossils from the Upper Silurian of S. Felix, Laundos, Portugal, and decided that *Plectrodus*-proper at least was a jaw, although *Sclerodus pustuliferus* was undoubtedly part of the cornu of the Cephalaspidian *Eukeraspis*.

Later studies have convinced me that the true *Plectrodus* (as typified by *P. mirabilis*) is indeed a jaw, and that it most closely agrees with the toothed jaws of the Lower Devonian Acanthodian *Ischnacanthus*.[2] I am, therefore, much indebted to Mr. W. Wickham King, F.G.S., for the opportunity of examining the microscopical structure of an unusually large specimen, probably of a new species, which he has recently found in the Downtonian of Baggeridge, S. Staffordshire. The hard base to which the teeth are affixed proves to consist of almost structureless translucent calcified tissue in which there are occasional streams of elongated cellular spaces, irregular in shape, and sometimes with traces of ramifying canaliculi. It thus agrees exactly with the corresponding tissue in *Ischnacanthus*.

In this connexion it is interesting to add that both in Oesel and in Portugal separate whorls of teeth such as occur in front of the lower jaw of *Ischnacanthus*,[3] have been found in the same rocks as *Plectrodus*.[4] On the other hand, no typical dermal tubercles of Acanthodian fishes have hitherto been recognized in any Upper Silurian formation, and the occurrence of Acanthodian fin-spines is uncertain. We may, therefore, conclude that the toothed Acanthodians of the Lower Devonian were preceded in the Silurian by fishes with similar jaws, but the precise nature of these earlier fishes still remains to be determined.

VI.—On the Geology of the District from Cil-y-Coed to the St. Annes–Llanllyfni Ridge (Carnarvonshire).[5]

By E. Wynne Hughes, M.Sc., F.G.S.

(*Concluded from January Number, p. 25.*)

B. Pre-Cambrian, Rhyolitic Series.—(i) At the south-west end of the Craig-y-Dinas mass we find exposed a rock similar in every respect macroscopically to that which is found at Cil-y-Coed. Unfortunately it cannot be followed far, as the land is completely under drift, the top of Craig-y-Dinas itself being capped by a thick layer of drift.

[1] F. Priem, "Sur des Poissons et autres Fossiles du Silurien supérieur du Portugal": Communic. Serv. Géol. Portugal, vol. viii, p. 3, pl. i, figs. 7–10, 1910.

[2] A. S. Woodward, *Catalogue of Fossil Fishes in the British Museum*, pt. ii, 1891, p. 20. B. Dean, "Notes on Acanthodian Sharks": Amer. Journ. Anat., vol. vii, p. 209, figs. 1–10, 1907. E. S. Goodrich, in Lankester's *Treatise on Zoology*, pt. ix, 1909, p. 190, fig. 160.

[3] A. S. Woodward, Presidential Address, Quart. Journ. Geol. Soc., vol. lxxi, p. lxvi, 1915.

[4] *Campylodus sigmoides*, J. V. Rohon, loc. cit., p. 52, pl. i, fig. 25, 1893; *C.* (?) *delgadoi*, F. Priem, loc. cit., p. 5, pl. i, figs. 11–15, 1910.

[5] Plates I and II and two maps, which illustrate this paper, will be found with the first part in the January Number, pp. 13 and 15.

(ii) Five hundred yards almost due north of Craig-y-Dinas, near the farm of Eithinog-Wen, a small amount of solid rock is present. A careful examination shows that this rock again compares closely with the rhyolitic series of Cil-y-Coed. Porphyritic quartz and pink felspars can be seen even in hand specimens. The groundmass is fine-grained, compact, and felsitic, differing only from the Cil-y-Coed rhyolites in its pink coloration. Beyond Eithinog-Wen a close search of the slope of the ridge, that runs in a northerly direction here, disclosed no further exposures. The large amount of debris, however, that is present everywhere at the foot of the ridge suggests the presence of the rhyolitic rock.

(iii) At Bryn-mawr, 1,500 yards to the N.N.E. of Craig-y-Dinas and 1,000 yards from Eithinog-Wen, several rock masses are exposed. The distance between the first and last of these exposures is fully 600 yards. They all occur near the top of the ridge, and are undoubtedly portions of the same mass. The line of outcrop, if continued in a southerly direction, would pass through the exposures at Eithinog-Wen and Craig-y-Dinas. The largest of these exposures is the quarry near the roadway close to Glyn-Llifon Park. It is at present being worked for road-metal. In some cultivated land on the north side of the road further exposures of this rock are also to be seen.

In hand specimens all the rocks compare closely with one another, showing porphyritic crystals of quartz and felspar in a fine-grained and compact groundmass. Several microscopic sections were examined, and they bring out the close resemblance between these rocks and the rhyolitic series at Cil-y-Coed. They show the presence of porphyritic crystals of quartz and both orthoclase and plagioclase. The quartz crystals are much more numerous than the felspars, but many of the latter still show multiple twinning. The groundmass is cryptocrystalline, with patches sometimes coarser and sometimes finer-grained, and it frequently shows good fluxion structure. (Pl. I, Fig. 1.)

We have here, then, a rock very similar, both macroscopically and microscopically, to the rhyolitic rocks of Cil-y-Coed.

C. Summary of the Succession.—We have, then, in the area between Pentwr and Bryn-mawr:—(i) Cambrian: (*a*) green slates at Ysgubor-Wen, (*b*) green grit band at Pentwr, (*c*) purple slates at Llech-y-dwr, (*d*) fine and coarse grits at Craig-y-Dinas, and also (*e*) a much cleaved conglomerate at Craig-y-Dinas, all with a dip of 50° S.S.E., lying upon (ii) Pre-Cambrian, (*f*) rhyolites and tuffs exposed at Craig-y-Dinas, Eithinog-Wen, and Bryn-mawr.

D. Relation to the Surrounding Areas.—(i) South-east of Pentwr we have already noted the occurrence of Ordovician slates on Y Foel. These can be traced through Tai-lon to Pen-y-garreg and beyond.

(ii) Unfortunately the Cambrian slates and grits cannot be similarly traced to Cil-y-Coed. The strike of the beds in the two localities suggests the presence of a fault in the intervening country, but no other evidence of it could be obtained, though this is the direction of the fault marked on the Survey map (1850).

(iii) To the west and north-west the country is flat and low-lying. No solid rock was found anywhere in this direction.

(iv) The most northerly exposure of the Pre-Cambrian rhyolite series is within 400 yards of the boundary assigned to the St. Annes–Llanllyfni ridge in the Geological Survey map (1850). The nearest locality on this ridge where solid rock is exposed is at Parc Pant-dy, 800 yards due east of Pen-y-groes and a mile and a half east of Bryn-mawr. Referring to the rocks at this end of the ridge, the Survey memoir states :—

"Further south the conglomerate forms the highest points of Moel Tryfan and Mynydd Cilgwyn, where it is partly metamorphosed into a sort of talcose schist and conglomerate. Beyond this it has been either completely obliterated, or, curving round to the east near the crest of the hill, it is cut off by a fault which throws the superincumbent purple slate directly against the porphyry. It is seen that the grits and lower conglomerates disappear at Mynydd Cilgwyn, but the purple slates that are interstratified with these follow an unbroken line to the neighbourhood of the turnpike road near Llanllyfni. The general character of the porphyry is that of a felsitic rock with an amorphous grey felspathic base containing small crystals of quartz, which are often somewhat granular, sometimes hexagonal, and sometimes they seem to be four-sided prisms.

" . . . It also contains small distinct crystals of glassy felspar. The base of the conglomerate is highly felspathic and sometimes crystalline, enclosing pebbles of felspathic trap, quartz, quartz rock, purple and black slate, and jasper. The whole mass is altered, and it is easy to note first: the disappearance of the granular structure in the conglomerate or sandy matrix and its gradual assumption of a porphyritic character, with small crystals of felspar embedded, while the enclosed pebbles still retain their distinctive form; and again, approaching the recognised porphyry the hard outlines of the pebbles in the conglomerate gradually melt away till they become undistinguishable in the general fusion of the rock, and the view that the porphyry is not an intrusive mass is aided by the fact that it is impossible to define any line of demarcation between conglomerate and porphyry."[1]

Evidently, then, we have on the St. Annes–Llanllyfni ridge a succession very similar to that at Craig-y-Dinas and Cil-y-Coed. In consequence, the south-west portion of the ridge between Moel Tryfan and the village of Llanllyfni was carefully examined.

3. The St. Annes–Llanllyfni Ridge.

A. Moel Tryfan.—The conglomerate at the top of Moel Tryfan seems outwardly identical with that at Cil-y-Coed. The pebbles are well rounded and of various sizes, though seldom more than 3 inches long. They are mainly of volcanic origin and are enclosed in an argillaceous matrix. There are also quite a number of quartzose pebbles of a type which is of rare occurrence in the conglomerate at Cil-y-Coed and Craig-y-Dinas, and the matrix is distinctly more argillaceous. On the top of Moel Tryfan there are no exposures of the quartz-porphyry or the quartz grit, but not more than 200 yards to the east of the conglomerate we find, at the Alexandra Slate Quarry, a great thickness of purple slate.

From this quarry an adit has been driven east and west right through the mountain. An examination of the rocks in this adit shows that a quartz grit occurs here on the eastern side of the

[1] Mem. Geol. Surv., vol. ii, p. 143, 1866.

conglomerate. Both the conglomerate and the quartz grit dip steeply to the south-east. A further point of interest is the existence of several well-marked faults, running north-east to south-west. These faults have the same direction as the fault between the grits and the Ordovician slates on the south-east side of Cil-y-Coed.

Several thin sections from the conglomerate in the adit were examined; they show that the conglomerate bears a close resemblance to that at Craig-y-Dinas and Cil-y-Coed. Thin sections of the grit from the two localities are also very similar, though perhaps the Moel Tryfan grit approximates more closely to a true quartzite.

The adit shows that the whole mass has undergone great disturbance, there being at least six faults visible in the adit, with the result that the structure is highly complicated. The conglomerate, for instance, is only 12 feet thick in the adit, whereas on the mountain top it has an outcrop fully 120 feet wide. Between the conglomerate and the porphyry at the west end of the adit, is a thickness of fully 200 yards of green slate, grit, gritty slate, and a green chloritic rock. Whether these slates and grits are Lower Cambrian or Pre-Cambrian is a question of some difficulty which I hope to investigate at a future date.

An examination of the adit then shows that—

(*a*) The conglomerate and quartz grit here bear a close resemblance to those at Cil-y-Coed and Craig-y-Dinas.
(*b*) They are in the same relative position.
(*c*) Their dip, although steeper, is in the same direction.
(*d*) As at Craig-y-Dinas, they are overlain by purple slate.
(*e*) The conglomerate in the adit does not lie directly on the quartz-porphyry.
(*f*) The matrix of the conglomerate is more argillaceous than that at Craig-y-Dinas and Cil-y-Coed.

B. Bwlch-y-llyn and Cilgwyn.—The conglomerate was traced in a south-westerly direction. At Bwlch-y-llyn the quartz grit also comes to the surface, and is again lying directly upon the conglomerate on its south-east side. An examination of microscopic sections cut from specimens in this locality again brings out a close resemblance between the grit here and that at Cil-y-Coed and Craig-y-Dinas. Like the latter, the grit at Bwlch-y-llyn ranges from fine to coarse, becoming more quartzitic from north-west to south-east. (Pl. II, Figs. 4, 6.)

From this point on, the conglomerate forms the high ground on Mynydd Cilgwyn, and it persists in a south-westerly direction along the whole length of the mountain. On the south-west slopes of the mountain, however, it disappears in the manner indicated in the Survey memoir. The pebbles in it, on this portion of the ridge, are certainly less numerous, but they are decidedly larger than at Moel Tryfan, and, what is still more interesting, the matrix is distinctly more felspathic. In hand specimens and under the microscope this gritty matrix could hardly be distinguished from the gritty matrix of the conglomerate at Cil-y-Coed. (Pl. II, Figs. 1, 2.)

Owing to the presence of several quarries on the east side of the ridge, the purple slate can easily be traced in a S.S.E. direction from Moel Tryfan to Cilgwyn. At Cilgwyn it is exposed at the

Old Cilgwyn and Veingoch quarries. The former of these two quarries lies only 250 yards away from the conglomerate, but does not expose the grit.

On Mynydd Cilywyn, moreover, the quartz-porphyry is exposed in several places, always to the west of the conglomerate, but the exact line of junction could not be seen. Several microscopic sections of the quartz-porphyry were examined, and here again the resemblance to the rhyolitic rocks of Bryn-mawr and Cil-y-Coed is most marked. The rocks contain porphyritic crystals of quartz and felspar embedded in a cryptocrystalline matrix which grades to microcrystalline in a patchy manner. It will be interesting to record here Bonney's description of microscopic sections from this ridge. He states :—

"The general type is a compact dull felsite with porphyritic crystals of felspar and grains of quartz closely resembling some modern rhyolites. On Moel Gronw angular fragments of a pinkish tint are scattered through the general mass. Again, some parts are crowded with quartz grains, while others are comparatively free of these, and occasionally a spherulitic structure is observed. The rock was probably originally vitreous, and there are abundant fresh examples of the most perfect flow-structure in the rock." [1]

This description compares very closely with that already given of the Cil-y-Coed and Bryn-mawr rhyolitic rocks.

C. Clogwyn Melyn to Caer Engan.—On the southern slopes of Mynydd Cilgwyn the conglomerate stops abruptly. All the lower slopes of the hill on this side are composed of rhyolitic rocks very badly sheared. A careful examination of the area disclosed no exposure of either conglomerate or grit, although a large amount of solid rock is exposed, all of which is massive rhyolite becoming more and more sheared towards the east. As indicated in the Geological Survey Map the rhyolite in this area is brought up against the purple slates. The rhyolite was traced through Parc Pant-dy to the lower roadway going from Pen-y-groes to Talysarn. Here it stops abruptly. But a small area of the rhyolite is exposed again at Caer Engan, 500 yards to the south-east of the nearest exposure in the main mass. In addition, a very narrow band of the conglomerate is found on the south-east side. It is badly crushed and the pebbles almost unrecognizable. The matrix is similar to that at Moel Tryfan, being argillaceous rather than felspathic. The greater portion of the hill, however, is composed of a felsitic rock, which both in hand specimens and in microscopic sections resembles the light variety at Cil-y-Coed ; but whatever fluxion structure it may contain is obscured by shearing.

Furthermore, 200 yards to the east of Caer Engan there is a small quarry in purple slates, but there is no exposure of grit in the intervening area.

D. Summary of the Succession.—We have, then, on the St. Annes–Llanllyfni ridge—

(i) Rhyolitic rocks, conglomerate, and quartz grit at Moel Tryfan.
(ii) Conglomerate and quartz grit at Bwlch-y-llyn.
(iii) Rhyolitic rocks and conglomerate at Mynydd Cilgwyn.
(iv) Rhyolitic rocks and conglomerate at Caer Engan.
(v) Purple slates all along the eastern side of the ridge.

[1] Q.J.G.S., vol. xxxv, p. 312, 1879.

IV. Conclusion.

The different formations at all the above localities on the St. Annes–Llanllyfni ridge lie in the same relative position to one another as the purple slates, grits, conglomerate, and rhyolitic series at Craig-y-Dinas, and the grits, conglomerate, and rhyolitic series at Cil-y-Coed. Further, the different formations are each to each lithologically similar. This resemblance is well brought out in Plate II, showing microphotographs of the conglomerate: Fig. 1, from Cil-y-Coed; Fig. 2, from Mynydd Cilgwyn; the fine grit: Fig. 3, from Cil-y-Coed; Fig. 4, from Bwlch-y-llyn; the coarse grit: Fig. 5, from Cil-y-Coed; Fig. 6, from Bwlch-y-llyn.

The evidence seems, therefore, conclusive that the series at Cil-y-Coed and Craig-y-Dinas are of the same age as those of the St. Annes–Llanllyfni ridge. Accepting the view, usually held, that the porphyry on this ridge is pre-Cambrian and that the conglomerate is basal Cambrian, we have—

1. At Cil-y-Coed—Lower Cambrian grits and conglomerate lying on Pre-Cambrian rhyolites and tuffs.
2. At Craig-y-Dinas—Lower Cambrian green and purple slates, grits, and basal conglomerate lying on Pre-Cambrian rhyolites.
3. At Bryn-mawr—Pre-Cambrian rhyolites and tuffs.

Pre-Cambrian Rhyolites and Tuffs.—To sum up, the solid rocks exposed in the area between Cil-y-Coed and the village of Pen-y-groes comprise a volcanic series of rhyolitic type, probably Pre-Cambrian, overlain by a series of conglomerates, grits, and slates of Lower Cambrian age. This sequence represents substantially the succession which obtains in the main portion of the St. Annes–Llanllyfni ridge to the north-east; and it is clear that the solid rocks of the St. Annes–Llanllyfni ridge extend at least 3 miles further south-west than is represented in the Geological Survey Map.

In conclusion, I desire to express my indebtedness to Mr. C. J. Edwards for suggesting the work on Cil-y-Coed and for several photographs, to Dr. Cox for reading through the manuscripts and for various suggestions during the course of the investigation, and to Dr. Gordon for his help in connexion with the microphotographs.

REVIEWS.

I.—The Geography and Geology of West-Central Sinai. By John Ball, Ph.D., D.Sc., F.G.S., A.R.S.M., Mem. Inst. C.E. pp. ix, 219, with two geological maps printed in colour, 22 plates, and 54 text-figures. Cairo: Government Press, 1916. Price 30 P.T.

THIS important work owes its origin to the discovery of ores of manganese and iron in the Sinai Peninsula by the late Mr. Thomas Barron during his reconnaissance survey of a vast area in Western Sinai in the years 1898–9. Prospecting followed, the Sinai Mining Co. was formed to exploit the deposits, and Dr. Ball was deputed by the Director of the Geological Survey of Egypt to carry out a detailed topographical and geological survey of the area in which the more important deposits occur. He has produced an accurate map of an area of 380 square miles limited by the parallels of 29° 15′ and 28° 56′ 20″ N. lat. and by the meridians of 32° 9′ 35″ and 33° 27′ 30″ E. long. on a scale of 1 : 50,000, on which the distribution of the various geological formations, ranging from the granite and gneiss of pre-Carboniferous age through the Carboniferous, Cretaceous, and Tertiary to the Pleistocene and Recent deposits of alluvium and blown sand, is laid down. The topographical and geological details were recorded simultaneously, and as an illustration of Dr. Ball's skill and neatness as a surveyor it may be mentioned that the maps are based on direct photographic reproductions of the field-sheets. In addition to the general map, the work is illustrated by a larger scale map (1 : 25,000) of the environs of Um Bogma, where the chief mines are situated, a plate of sections, numerous photographs, and a large number of text-figures, including pen-and-ink sketches of the most typical fossils drawn by the author from actual specimens.

After describing the general features of the district, which consist of highly dissected tablelands and assemblages of rugged granitic peaks, with occasional more open areas, the author gives an account of the survey operations, of the methods adopted in laying out the base-line, in determining its geographical position, and in connecting up the triangulation with that of Egypt proper. Then follow chapters dealing with the topographical features—the wadis, the mountains and the plains—and with the geology.

In the centre of the area lies a broad sandy plain at a height of about 500 metres above sea-level, on which the base-line was laid down. This is bounded on the north by the formidable escarpment of Gebel el Tih, the edge of which is from 500 to 600 metres above the plain and extends from east to west in a somewhat sinuous curve. The base of the escarpment is formed of Nubian Sandstone, then follow 200 metres of fossiliferous Cenomanian clays, marls and limestones, which are capped by beds of Turonian limestone. The escarpment forms the southern termination of a deeply dissected plateau which stretches far to the north, and it is a remarkable fact that although the valleys descend rapidly from the edge in that direction, none appears to have been beheaded by the recession of the escarpment. Many points on the edge have been accurately fixed.

South of the central plain is a wild country with only relics of plateau structure, in which many mountains rise to heights of 700 or 800 metres above the sea and one to over 1,000 metres. It consists of the pre-Carboniferous complex of granite and metamorphic rocks, on the planed-down surface of which rest strata of Carboniferous age. The time available did not admit of any attempt to separate the rocks of the complex, which is presumably Archæan. The Carboniferous rocks consist of a lower sandstone (130),[1] a middle limestone with fossils, similar to those occurring in Derbyshire and Yorkshire (40), and an upper sandstone with *Lepidodendron* (130). To the west of the central plain this upper sandstone underlies the Nubian Sandstone,

[1] The figures in parentheses represent thicknesses in metres.

which it closely resembles. This point is one of great interest on account of the discussion which has taken place as to the age of the Nubian Sandstone. In the region we are considering the vast period of time separating the Carboniferous Limestone from the marine Cenomanian clays is represented by 650 metres of sandstone, which are conformable to the rocks below and above, and in which no break can be detected. Dr. Ball separates the lower portion of this series (130) under the name of Upper Carboniferous Sandstone, on account of the occurrence of fossils of the *Lepidodendron* type, from the upper portion (500) to which he restricts the name of Nubian Sandstone. The only traces of fossils found in the upper portion are a piece of silicified wood "similar to that which occurs in the Nubian Sandstone of Egypt", and a thin layer of very impure coal. Owing to the discovery of *Inoceramus* in the Nubian Sandstone of Aswan and the intercalation of the sandstone with the overlying marine Cretaceous in other parts of Egypt this formation is now generally regarded as being of Cretaceous age. Until quite recently no trace of marine fossils of Triassic or Jurassic age has been found either in Egypt or Sinai, but Dr. Ball refers to a discovery of Jurassic deposits in the northern portion of the peninsula, and suggests that part of the Nubian Sandstone may be of the same age. Details of this important discovery do not appear to have been made public.

So far we have been referring to about three-fourths of the area covered by the map. This portion is bounded on the west by a series of important faults following a general direction a little east of south, roughly parallel to and at an average distance of about ten kilometres from the Gulf of Suez. The remaining portion consists principally of Campanian strata, but contains also representatives of the Eocene and Miocene periods. At one point Miocene rocks are faulted against the Lower Carboniferous Sandstone, and the throw is estimated at probably not much less than 2,000 metres. The faulting is regarded by the author as belonging to the close of the Miocene period; but the possibility of its having commenced at an earlier period must not be overlooked.

Campanian strata (300?) form a highly dissected hilly country of a dazzling white aspect. Eocene strata appear to rest conformably on the Campanian. They are much thinner than those on the opposite side of the Gulf of Suez and in the Nile Valley. The Miocene rocks occur in detached patches and comprise conglomerates, gritty limestones, clays, and chalky rocks often impossible to distinguish from Eocene or Cretaceous in the absence of fossils. The author sums up his observations on the Miocene deposits in this part of Sinai by saying that "the more easterly portions are characterized by great accumulations of conglomerates and grits, indicating that the old shore ran approximately along the line of the great fault already referred to, while farther to the west there is increasing predominance of limestones, clays, marls, and gypsum, indicating deeper water conditions for certain beds".

The geological history of Egypt during post-Eocene times is of great interest, but it is difficult to correlate the available information. The prolonged hydrocratic movement which lasted during the

Cretaceous and Eocene periods was followed by a geocratic movement in Oligocene times, when the fluvio-marine beds of the Fayum were formed with the remarkable deposits containing mammalian remains at their base. To this succeeded another hydrocratic movement in Miocene times. Miocene deposits occur in northern Egypt, on the borders of the Gulf of Suez, and in the neighbourhood of Ras Mohammed. They occur at different levels and sometimes have the character of beach deposits. Did the earlier Miocene deposits advance over a planed down surface of older rocks? This is suggested by Dr. Ball's work, for it is impossible to avoid the conclusion that the Cretaceous and Eocene deposits once extended over the whole area. Moreover, a small patch of Miocene strata, wedged in between two faults just north of Gebel Sarbut el Gamal, is represented on the map as resting both on Nubian Sandstone and on Cenomanian, whereas Miocene rests on Campanian, without any intervention of Eocene on the mountain itself, of which it forms the summit.

As evidence of the great differences of level at which Miocene rocks occur, it may be pointed out that the boring for oil at Gebel Zeit[1] ended at a depth of about 1,100 metres below sea-level in rocks which are supposed to be of Miocene age, whereas the top of Gebel Sarbut el Gamal is 642 metres above the sea, making a difference of 1,742 metres. How far these differences of level are to be accounted for by deposition at different times while geographical evolution was going on, and how far they are due to movements of elevation and depression affecting large areas or to faults subsequent to deposition, cannot be determined with precision at present, but the last-mentioned cause has certainly played an important part. Basalt sills and dykes occur at many points in the district. They are all referred by the author to the Miocene period.

The ores of manganese and iron (pyrolusite, psilomelane, wad, and hæmatite) occur at the junction of the Carboniferous Limestone and the underlying sandstone in certain places. They form irregular deposits which are only found in the neighbourhood of faults and become thicker and richer as the faults are approached. Where they occur certain dolomitic limestones, containing small amounts of manganese and iron, have partially or wholly disappeared, and it is suggested that the circulation of water along the fault fissures has removed the carbonates of lime and magnesia from the limestones and left behind the manganese and iron as oxides. The principal objection to this theory is that the amount of manganese in the dolomites which have been analysed is very small—less than ½ per cent. Is it possible that beds much richer in carbonate of manganese, like those occurring in Merionethshire, are present but not exposed?

In these days, when there is a marked recrudescence of old superstitions, not confined to geology, it is interesting to note that Dr. Ball, so far as this district is concerned, attributes the surface inequalities directly to erosion. After pointing out that valleys

[1] Explanatory notes to accompany the Geological Map of Egypt by W. F. Hume, Cairo, 1912.

sometimes coincide with faults he says: "It is important to note that the same fault which coincides with a deeply eroded wadi along one part of its course may cut across a high mountain tract in another part, and frequently at the latter place there is not the slightest change in the contour of the surface to mark the line of fault. Nothing of the nature of a 'rift' is anywhere visible; faults have governed the position of drainage lines in places, but erosion alone has removed the material from the valleys." In discussing the relation of the faults to the Gulf of Suez, which has been regarded as a trough subsidence, he refers to his papers in the Geological Magazine [1] in which he has brought forward arguments in favour of the view that it is a submerged land valley.

Enough has been said to show that this clearly written, beautifully illustrated, and well-printed monograph is an important contribution to our knowledge of the geography and geology of the Sinai peninsula.—J. J. H. T.

II.—A Text-Book of Geology. Part II: Historical Geology. By Charles Schuchert. pp. viii + 405–1026, xxxvii plates printed in text, text-figures 312–522, and Geological Map of North America. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd. 1915. Price 12*s.* nett.

The first part of this text-book, dealing with Physical Geology, was reviewed in the Geological Magazine for September, 1916. Physical Geology is much the same the world over, though certain aspects may be more studied, or certain theories more favoured, in one country than in another. Historical Geology on the other hand, unless it be treated from the view-point of that observer in space whom Suess imagined, almost inevitably takes its colouring from the native country of the historian. This tendency is accentuated, and naturally so, when the exposition is based on lectures to the students of a single university. Above all is the difference marked between an American and a European treatment of the subject. We are therefore not surprised to find in Professor Schuchert's book, embodying as it does a course delivered to undergraduates of Yale, a presentation of historical, or at any rate of stratigraphical, geology, which to one brought up on Sedgwick, Murchison, Geikie, and Prestwich, might almost seem to be the account of another world. We do indeed find such familiar names as Cambrian, Carboniferous, and Cretaceous (and we must rejoice that Professor Schuchert's publishers or his own better judgment have not permitted him to use the Cambric, Carbonic, and Cretacic, which he has long sought to introduce); but even these household words have a novel content. The name Carboniferous has long been restricted by American geologists to the equivalent of our Coal-measures. Then this gave place to "Pennsylvanian", the Lower Carboniferous becoming "Mississippian"; and now the latter is split into an upper system, the "Tennesseian", including all formations from the Kaskaskia

[1] "Origin of the Nile Valley and the Gulf of Suez," Geol. Mag., 1910, p. 71, and "The Gulf of Suez", Geol. Mag., 1911, p. 1.

down to the Warsaw, and a lower "Waverlian", continuing from the Keokuk to the unfamiliar Chattanooga. These rather uncomfortable system-names are adopted from Mr. E. O. Ulrich, who, however, spelt them differently. In similar fashion the name "Cretaceous" is restricted by Mr. Schuchert to formations corresponding to our Upper Cretaceous, i.e. down to the beginning of Cenomanian time; the preceding ages, from Albian to Neocomian inclusive, are erected into the Comanchian period, at least so far as North America is concerned.

It may be gathered from the preceding paragraph that, except for the Eras, and to an incomplete extent for the Epochs, Professor Schuchert does not attempt to overcome the difficulties inherent in geographical treatment by any use of universal Time-names. For him such ages as 'Tournaician' [*sic*] or 'Cénomanian' [*sic*] are just as local as the Elizabethan period or the Carlovingian epoch. No living geologist is better fitted to discuss questions of correlation, at all events for the Palaeozoic era, than is Professor Schuchert, and the fact that he is deliberately provincial may be held to indicate that in his opinion the time is even yet not ripe for comparison of the isolated histories with any universal Time-standard. Such an opinion does not well harmonize with the widely held view that the rhythmical movements of the earth's crust are at the base of the whole march of the world and its varying tempo, or with the knowledge we already have of those movements—a knowledge so well illustrated by Professor Schuchert's numerous maps, and emphasized by the varied names that he provides for uplifts and disturbances, such as the delightfully christened Shickshockian. No doubt, as he says, we have still much to learn in Europe as in America; and the more we know the more impossible will be exact correlation of far distant strata. But the practical application of a Time-scale will always help us over many difficulties, and will at least show just where our knowledge is defective.

The book is meant to be a guide for American students, and for such a purpose it seems well adapted. Apparently the students of geology at Yale are not expected to have any knowledge of elementary zoology and botany, and so the lecturer has ever and anon to break the thread of his discourse in order to impart information concerning the anatomy of Mollusca, the origin of lungs, the classification of Pteridophyta, the physiology of Amphibia, amniotic development, human embryology, and other matters properly belonging to other branches of study. However well Professor Schuchert deals with these subjects, the space devoted to them has necessarily to be taken away from stratigraphical geology, and the part that suffers is, as already indicated, the history of other countries. For us on this side of the Atlantic, therefore, the book must serve, not as a text-book for our students, but as a useful conspectus of American geological history. Here the rapid advance has of late introduced so many changes that one is grateful for a handy volume in which to follow the succession of geographical forms, and from which to extract the meaning of Appalachicola, Arikaree, Swearinger, Bertie, Cannonball, Kittatinny, and Mauch Chunk. One must also be grateful for some admirably written sections on the beginnings of earth-history by Professor Barrell, and for a well-illustrated chapter on Dinosaurs by Professor R. S. Lull. In brief, this is an original and stimulating book, where fact and theory are happily mingled, and the tangled threads of many complicated series of events reduced to an orderly and attractive pattern.

III.—Meteorites: their Structure, Composition, and Terrestrial Relations. By O. C. Farrington. pp. x, 233, with frontispiece and 65 figures in text. Chicago: published by author, 1915. Price 8*s.* 6*d.*

THE absence of a comprehensive and up-to-date book on meteorites has undoubtedly been a factor in confining the interest in this subject to a comparatively small number of geologists. The admirable introduction to this study in the handbook to the collection in the Natural History Museum is of course limited in scope, while Cohen's *Meteoritenkunde*, which was intended to cover the full ground of the subject, was unfortunately little more than half finished at the author's death. Dr. Farrington's book, therefore, fills a gap in scientific literature and will be indispensable to the student who desires a general knowledge of the subject.

The book opens with a discussion of the criteria whereby meteorites may be distinguished from terrestrial material, and emphasis is laid on the superficial and chemical characteristics by which the former may be discriminated when, as is generally the case, the fall has not been observed. Several chapters are devoted to the fall of meteorites, while the succeeding sections are concerned with the form and size of these bodies. As is to be expected, the discussion of the composition and structures is very full, the explanation of the octahedral structure so common in 'irons' and the account of the structures found in 'stones' being admirably lucid. In the description of the mineral species a large amount of space is devoted to the three types of nickel-iron, but this constitutes the least satisfactory portion of the book. Thus plessite is explained by analogy with the system silver-copper, as a eutectic developing probably from solid solution, but no mention is made of the recent metallographic work on the system iron-nickel.[1] The investigations of Osmond and Cartaud, Tammann, and particularly Ruer have shown that γ-iron and β-nickel are isomorphous and that this solid solution on cooling undergoes a number of changes in the solid state. α-iron and α-nickel, the low-temperature forms, also give solid solutions, and kamacite is to be regarded as a nearly saturated solid solution of α-nickel and α-iron, and not, as Dr. Farrington hints, as a compound of constant composition, $NiFe_{14}$. The only compound in the system has the composition Fe Ni, and tænite is considered to be a solid solution of α-iron and this compound, while plessite is a eutectoid of kamacite and tænite, separating from solid solution.

[1] A useful summary of this is given by Desch, *Metallography*, 2nd ed., 1913, pp. 383–5.

The author uses Rinne's term 'eutropic' in place of 'eutectoid', but this is inadvisable as 'eutropic' had previously been used in another crystallographic sense by Linck in 1896, while 'eutectoid', first suggested by Howe in 1903, has also priority over 'eutropic' (suggested by Rinne in 1905) and has been generally adopted.

For a long time the structure of meteorites was regarded as metastable, as it could be destroyed by annealing and a granular texture—occasionally found naturally—obtained. Recently, however, Benedicks, by very slow cooling, has obtained plessite and reproduced the octahedral structure. Hence the granular structure is to be regarded as metastable, and the difficulty in reproducing the usual meteoric structure is to be ascribed to the low rate of diffusion inhibiting changes in the solid state.

In the chapter on classification the only system given is Brezina's modification of the Rose-Tschermak classification. It would have added to the interest of the book if the author had given his own interesting classification based on the American quantitative system for igneous rocks, and Berwerth's rational system founded on the synthetic work on nickel-iron. The recent genetic one, devised by Prior, was, of course, published after this book appeared.

The illustrations are excellent and the letterpress very clear, though there is a misprint in figure 53 and another on p. 139. The use of such a contraction as 'A.N.H. Wien' is by no means clear. Nevertheless the book can be confidently recommended as the best general introduction to the study of meteorites which has yet appeared, and should be in the possession of everyone interested in the subject.

A. S.

IV.—Radioactivity and Mountain Building.

The Compression of the Earth's Crust in Cooling. By Harold Jeffreys. Phil. Mag., xxxii, pp. 575–91, December, 1916.

THE view that mountain-building owes its principal cause to the contraction of the earth has been widely adopted by geologists. The subsidiary view that the alleged contraction is due to loss of heat has not met with equal success. The calculations of T. Mellard Reade, made before the discovery of radioactivity, indicated that the circumferential shortening of the globe (in cooling from a molten state to its present condition during a period of 100 million years) could not exceed 10·5 miles. This figure is only a small percentage of the shortening implied by the existence of great mountain ranges. Moreover, various calculations of the *level of no strain* by Fisher, Reade, Davison, and G. H. Darwin gave results varying between 0·7 and 7·8 miles. That is to say, compressional deformations of the earth's crust must, on the older hypotheses, have been limited to a thin superficial shell which could never have accumulated the enormous stresses required for periodic mountain-building. Thus, in two directions, the thermal contraction theory was shown to be hopelessly inadequate to meet the facts. Consequently other causes of contraction have come to be invoked in recent years; among them, a molecular rearrangement of compounds in the earth's interior, which under high pressure may be supposed to involve a decrease in volume.

With the discovery of radioactivity and the realization of its fundamental importance in dynamical geology it became evident that the thermal contraction theory stood in urgent need of re-examination. The mathematical skill required for this task is of an order far beyond the attainments of most geologists, and Mr. Harold Jeffreys has come to our assistance by working out, in the light of our later knowledge, the group of problems involved. Using the thermal and radioactive data adopted by the present writer in a series of papers which have appeared in the pages of this Magazine, he has arrived at the following results:—

(*a*) The level of no strain is now at a depth of 79 km. (uniform distribution of radioactivity) or of 76 km. (exponential distribution).

(*b*) Every great circle of the earth has been shortened by 227 km. (uniform distribution of radioactivity) or by 133 km. (exponential distribution). To arrive at the radial shortening, these figures should be divided by 6·28.

(*c*) The surface of the earth has been diminished by crumpling by $5{\cdot}6 \times 10^6$ sq. km. (uniform distribution of radioactivity) or by $3{\cdot}3 \times 10^6$ sq. km. (exponential distribution).

In order to test these results Mr. Jeffreys has calculated from the mean height of existing mountain ranges the approximate diminution of the surface by crumpling. He finds the amount to be about $1{\cdot}8 \times 10^6$ sq. km., which is little more than half of the amount implied by the thermal contraction hypothesis in its new form (exponential distribution). It should be pointed out, however, that Mr. Jeffreys' calculation of the actual amount of diminution of the surface by crumpling gives only a minimum result, for it does not take into consideration the former existence of ranges that are now submerged or denuded to insignificant elevations. Most of the ranges measured are of post-Carboniferous age, and may therefore represent only a third or a quarter of the total crumpling since geological history began. The maximum circumferential shortening demanded by Chamberlin is about 300 km., corresponding to a surface diminution by crumpling of $7{\cdot}6 \times 10^6$ sq. km., more than twice as much as that found theoretically on an exponential distribution of radioactivity. Nevertheless, in spite of the fact that complete accordance has not yet been attained, it is evident that the theoretical and observed compressions are of the same order of magnitude, and it may confidently be asserted that the much abused thermal contraction hypothesis, thanks to radioactivity, has now been set firmly on its feet.

Arthur Holmes.

V.—Mineral Resources of the United States for 1914.

THIS is the 33rd of the admirable series of reports which was started in the early years of the United States Geological Survey. Year by year they give carefully prepared statistical information of the output of minerals in the country and of the imports from outside. As usual this report is divided into two main parts, of which the first deals with metallic and the second with non-metallic substances, the latter including fuels, structural materials (other than metals), chemical minerals, and precious stones. Each chapter is entrusted to a different writer, and each is issued separately as soon as it is ready. The date of publication of the several chapters is given on the wrappers, but disappears in the bound-up volume; the pagination is continuous, but separate throughout each part of the report, including the summary. The series is so well known that detailed criticism is uncalled for; it is sufficient to say that the present report is well up to the high standard of its predecessors.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *December* 20, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

Marie C. Stopes, D.Sc., Ph.D., gave an account of some recent researches on Mesozoic 'Cycads' (Bennettitales), dealing particularly with recently discovered petrified remains which reveal their cellular tissues in microscopic preparations. To make the significance of the various fossil forms clear, Dr. Stopes first showed some lantern-slides of living Cycads, and then pointed out that it was in their external features and in their vegetative anatomy only that the fossil 'Cycads' were like the living forms; the most important features, the reproductive organs, differ profoundly in the two groups, and the fossils were fundamentally distinct, not only from the living Cycads, but from all other living or fossil families.

The fossils representing the group that are most frequently found are (*a*) trunks, generally more or less imperfect casts or partial petrifactions, and sometimes excellent petrifactions preserving anatomical details and cell-tissues; (*b*) impressions of the foliage. Not infrequent are the detached impressions of incomplete 'flowers' or cones, of one cohort (the Williamsoneæ), while petrified fructifications are numerous in some of the well-petrified trunks of the Bennettiteæ. The described species of the group run into hundreds, but probably many of these duplicate real species, because the foliage, trunks, pith-casts, various portions of the fructifications, etc., have often been separately found and named. In very few cases have the different parts been correlated. The species of the foliage are the most generally known, as they are the most readily recognized with the naked eye; they have been described under a variety of generic names.

The following table gives the proved, or probable, associated parts of some members of the group:—

Foliage.	Trunk.	Fructifications.
Zamites spp.	*Bennettites* spp.	*Bennettites* spp.
Zamites gigas.	Attached, no separate name.	*Williamsonia gigas.*
Otozamites sp.	—	*Williamsonia spectabilis.*
Ptilophyllum pectinoides.	—	*Williamsonia whitbiensis.*
Anomozamites minor.	(Only slender branches known, no name.)	*Wielandiella angustifolia.*
Tæniopteris vittata.	—	*Williamsoniella coronata.*

Dr. Stopes exhibited slides of microphotographs of the stem and leaf-base anatomy of the group, including some unpublished details of *Bennettites maximus.* The roots of the group have hitherto been entirely unknown, and a slide was exhibited for the first time showing rootlets penetrating the leaf-bases of a petrified specimen (represented by a section in the Geological Department of the British Museum—Natural History). These roots probably belong to *B. saxbyanus*: they are covered with wonderfully petrified root-hairs, running uncollapsed through the silica matrix. They raise interesting questions concerning the possible chemical conditions of the infiltration of the silica. Illustrations were also exhibited of the famous complex 'flower' and cone-structures, and of Wieland's brilliant restorations of the same. Microphotographic slides were exhibited of the seed-cone of an interesting unpublished new species from the British Gault. This is beautifully petrified, and adds to our knowledge of the finer anatomy of the seeds and associated structures. It is also the largest cone of the Bennettitales yet known, though it occurs in the Gault, by which time the group appears to have begun rapidly to die out.

The following table indicates the distribution of a few of the most interesting representatives of the Bennettitales (including the cohorts Bennettiteæ and Williamsoneæ):—

Upper Cretaceous.	Very fragmentary and uncertain records; apparently the group is nearly or quite extinct.	
Middle Cretaceous:	The new large-sized seed-cone.	
Gault.	*B. morierei* ♀ (? described originally from the Jurassic).	
Lower Cretaceous:	Well-petrified trunks with fructifications.	
Lower Greensand.	*B. gibsonianus* (type-species of the Bennettiteæ).	
	B. maximus.	Throughout these periods in America, trunk-remains very abundant, often petrified and with fructifications, particularly from the Black Hills, South Dakota, and Maryland. *C. jenneyana*, *C. ingens*, *C. wielandi*, etc.
Potton Sands.	Trunks, e.g. *Colymbetes edwardsi.*	
Wealden.	Trunks (casts and petrifactions), foliage.	
	B. saxbyanus.	
Jurassic: Purbeck.	Trunks (casts and semi-petrifactions).	
	Buckland's original *Cycadeoidea* spp.	
	C. gigantea.	
Oolites.	Trunks, pith-casts, etc. Much foliage of various types. *Williamsonia gigas* and other fruit-impressions.	
	W. scotica.	
	Williamsoniella coronata.	Rich impressions in Mexico of *Williamsonia* and many foliage genera.
Lias.	Foliage and *Williamsonia* fruits (India).	
Rhætic.	*Wielandiella angustifolia* and foliage.	

The group is by far the most characteristic of all the plants of the Jurassic and Lower Cretaceous, during which periods its distribution was almost world-wide. It was locally, if not universally, dominant, and was the most highly evolved plant-group of the epoch of which we are cognizant.

Three chief points of interest are to be noted in the geological distribution of these plants: (*a*) that the most numerous highly specialized trunks reach their maximum in the Jurassic and Lower Cretaceous Periods, when their distribution was practically world-wide; (*b*) that the oldest and therefore presumably the most primitive type, *Wielandiella*, is externally less like the living Cycads than the commoner later forms, while these latter are utterly unlike the living genera in their fructifications; (*c*) that the geologically youngest cone is the largest yet discovered, occurring in the Gault when the extinction of the group appears already to have set in.

Contrary to what might have been anticipated from their external likeness to the living Cycads, coupled with their great geological age, the fossil 'Cycads' are much more complex and on a higher level of evolution than the living group. It seems to the author to be extremely unlikely that the fossil and the living forms have any direct phylogenetic connexion nearer than a remote, unknown, common ancestor. The mooted connexion between the fossil 'Cycads' and the Angiosperms is highly suggestive, but lacks data for its establishment.

A short discussion followed, and the thanks of the Fellows present were accorded to Dr. Stopes for her lecture.

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2. *January* 10, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Palæozoic Platform between the London Basin and Adjoining Areas, and on the Disposition of the Mesozoic Strata upon it." By Herbert Arthur Baker, B.Sc., F.G.S. With an Appendix by Arthur Morley Davies, D.Sc., F.G.S.

The author carries on the work of Dr. A. Strahan and Dr. Morley Davies in tracing the contours of the Palæozoic platform of the South-East of England. By comparing these with the contours of the base of the Gault, he determines the probable boundaries of the areas of the platform that were only submerged finally under the Gault sea. He analyses the effects of post-Cretaceous tilting and warping, and presents a map illustrating the contours of the Palæozoic floor at the end of the Lower Cretaceous Period.

He next discusses the successive Mesozoic overlaps on the platform, the probable areas that they respectively cover, and the relation of these to the tectonics of the platform itself. He claims that there is evidence for a second Charnian axis, parallel to that traced by Professor P. F. Kendall, proceeding south-eastwards through Norfolk and Suffolk, east of Kent, to the North of France. He further suggests that the area between these two geo-anticlines is a geo-syncline, which in Mesozoic times, in consequence of the accumulation of sediments within it, and the continued operation of Charnian movement, became converted into an anticline (as in the case of the Wealden area).

In an Appendix, Dr. Morley Davies discusses the interpretation of the Saffron Walden boring, and its bearing on the supposed inter-Charnian trough; he also points out evidence of a post-Cretaceous Charnian anticline under London.

2. "Balston Expedition to Peru: Report on Graptolites collected by Captain J. A. Douglas, R.E., F.G.S." By Charles Lapworth, LL.D., M.Sc., F.R.S., F.G.S.

The specimens of graptolites were collected from the rocks of the Inambari district in Peru by Captain Douglas, under whose name the collection has been placed in the Geological Department of the University Museum, Oxford. These fossils were forwarded by Professor W. J. Sollas to Professor C. Lapworth, who embodied the results of his study in a Report, of which the following is a brief abstract.

The specimens are recorded as all occurring in the same locality, but it is not known whether they were obtained from a single zone. The majority of the rock-specimens in which the graptolites occur are black and somewhat pyritous carbonaceous shales, usually well bedded and uncleaved, and the graptolites are in general well preserved. The lithology of the containing rocks and the mode of preservation of the graptolites are similar to those obtaining in the richest graptolite-bearing strata of Britain, Europe, and North America.

The forms apparently represented in the collection are *Logano-graptus logani*, Hall, a new species of *Goniograptus* (?), *Didymograptus stabilis*, Elles & Wood, and *D. bifidus*, Hall, *Phyllograptus angusti-folius*, Hall, *Glossograptus acanthus*, Elles & Wood, *Cryptograptus tricornis*, Hall, var. *Amplexograptus confertus*, Lapworth, and *A. cœlatus*, Lapworth.

Taken as a whole this graptolite fauna may best be compared with that of the Upper Arenig formation of Britain and its North American equivalents, answering to the Lower Llanvirnian of Hicks & Marr, and the *Didymograptus bifidus* zone of Elles & Wood and H.M. Geological Survey.

The assemblage of graptolites discovered in Bolivia a few years ago by Dr. J. W. Evans corresponds very closely with this Peruvian fauna, and was probably derived from the southward continuation of the same Andean graptolite band. The Peruvian forms in the Douglas Collection, like those from Bolivia, admit almost as close a parallelism with those of the Arenig–Llandeilo graptolite beds of Australia and New Zealand as with their representatives in the Northern Hemisphere.

Not only is the Douglas Collection of Peruvian graptolites instructive and valuable from the palæontological point of view, owing to the number and good state of preservation of the species represented, but it is of especial interest from the palæographical aspect, as affording additional proof of the identity (in general facies) of the graptolite fauna of the sea-waters of Lower Ordovician times in those regions of the globe which are now occupied by some of the dry lands of Britain, Eastern North America, Peru, Bolivia, Victoria, and New Zealand. Thus it greatly strengthens the inference that in Arenig–Llandeilo times there was open-sea communication admitting of the circulation of sea currents along some as yet undetermined line or lines, connecting the above-mentioned regions, which must have extended across the Equator and apparently throughout a length nearly equal to that of half the circumference of the globe.

II.—Edinburgh Geological Society.

December 20, 1916.—Dr. Flett, F.R.S., President, in the Chair.

The following papers were read:—

1. "Igneous Intrusive Phenomena at Upper Whitfield, near Macbiehill; and at Ravelrig and Kaimes Hill Quarries, Balerno." By T. Cuthbert Day, F.C.S.

The intrusive nature of the Upper Whitfield basalt was established by the discovery of upper and lower contacts with the sedimentary deposits. Details of a xenolithic structure in the igneous rock at the point of contact were given, and a peculiar marmorized dolomite associated with chert was described. Mention was also made of a case of metasomatism in basalt through the action of a deposit of dolomitized calcite.

A description was given of a peculiar tachylite in connexion with the intrusive olivine dolerite at Ravelrig and Kaimes Hill quarries, Balerno.

2. "On a Section in a Bore-hole in the Calciferous Sandstones, Upper Old Red Sandstones, and Lower Old Red Sandstone Lavas in the Grange District, Edinburgh." By D. Tait, H.M. Geological Survey.

Mr. Tait said that the geological horizon of the beds in the upper part of the bore are on the boundary between the Carboniferous and the Old Red Sandstone formations, but, as no fossils had been found in the bore, no sharp line could be drawn at their point of junction; possibly they form passage beds between them, since there were present, interbedded with each other, beds typical of both formations.

At a depth of 284 feet a fault breccia was passed through. This probably indicates a fault, with a downthrow to the south-west, but its importance is not known. From 389 to 397 feet cornstone bands and nodules were found, interbedded with red marly clay. At 399 feet the bore passed through the unconformity between the Upper Old Red Sandstone and the Lower Old Red Sandstone. The Lower Old Red Sandstone rocks are lavas of Blackford Hill Quarry type and a bed, 47 feet thick, of volcanic agglomerate. The total depth of the bore from the surface was 475 ft. 6 in.

III.—The Geological Society of Glasgow.

At a meeting of the Geological Society of Glasgow held on December 14, 1916, Mr. H. R. J. Conacher read a paper on "Oil-shales and Torbanites". The rocks of these types which occur in the Lothians yield, on destructive distillation, a characteristic crude oil which consists chiefly of paraffins, olefines, and naphthenes, and they thereby differ from ordinary coals, the liquid products of which contain but small amounts of these hydrocarbons. This peculiarity has been variously ascribed to the presence of vegetable matter derived from algæ or higher plants in a more or less decomposed state, animal matter from the fish, ostracods, etc., whose remains are abundant in the shales, to the presence of petroleum or other bituminous substances or to a hypothetical material called kerogen. The author described a series of experiments undertaken with a view to attaining a definite result, the method being to ascertain what material could actually be detected by means of the microscope, and to compare these constituents with the results of the distillation of the same samples.

In those shales which contain animal remains, the yield and quality of oil is independent of the amount of animal remains, but varies in proportion to the quantity and nature of the vegetable matter present. The latter consists of two distinct types. One portion seems to be macerated and carbonized plant-material, similar to that of which coal is composed, while the other portion is composed of certain yellow bodies which have been variously described as spores, fossil algæ, or globules of dried-up petroleum. It is these yellow bodies which yield the distillation products of oil-shales and torbanites. The evidence is against these bodies being spores, algæ, or petroleum, and it is shown that they are simply fragments of resin set free by the decay and oxidation of woody matter with which they had been originally associated, and that, by the physical action of pressure and shrinkage, structures had been developed simulating those of spores and algæ. The failure to obtain appreciable amounts of extract by means of the usual solvents is inconclusive, as it is known that the solubility of resins rapidly diminishes with increasing age. Further it has recently been found that the resinous material extracted from coal yields on distillation just such products as are got from oil-shales and torbanites. The author's view, therefore, is that both oil-shales and torbanites are derived from the same original materials as ordinary coals, but have reached a state of more complete elimination of the perishable parts, leaving the resins with a proportion of material derived from the decomposition of the woody substances, which in the case of oil-shales are mixed with a large proportion of mud.

Mr. J. Neilson read a paper entitled "The Auld Wives' Lifts, an Ancient Monument". He objected to the view that these stones had reached their present position through natural agencies by the subaërial weathering of a ridge, as the position of the stones in the centre of a shallow amphitheatre rendered the action of erosion negligible, while the surrounding rocks show little sign of alteration since Glacial times. The theory that their origin is due to ice-action is equally untenable, while there are likewise difficulties in the hypothesis that the structure is a "tor". The explanation advanced by the author is that the "Lifts" did not attain their present position by natural agencies, but that they were placed there by man, the blocks having been taken from the nearest escarpment. The whole structure belongs to the type of monument known as cromlech or dolmen, and the irregular form and small dimensions are probably to be explained by the fact that the chief consideration was the feat of raising the enormous blocks, the utility of the chamber beneath being of secondary importance.

CORRESPONDENCE.

PROFESSOR LOEWINSON-LESSING.[1]

Sir,—It was arranged in January, 1914, that a German translation of Professor Loewinson-Lessing's important memoir on the volcanoes of the central Caucasus should be published in Tschermaks Mitteilungen. Owing to the strike of the printers in Vienna the publication of the memoir was delayed till the summer, and before its issue war was declared. It has subsequently been published, and Professor Loewinson-Lessing is anxious that it should be understood by his English friends and fellow-geologists that the publication of this memoir in Austria was arranged *before the War* and that he has since then had no share in its production.

As Professor Loewinson-Lessing has asked me to explain why his memoir has appeared in an Alien journal during the course of the War, I shall be much obliged if you would issue this explanation.

J. W. Gregory.

Geological Department, University, Glasgow.
January 17, 1917.

OBITUARY.

ERNEST SWAIN.

Born January 15, 1843. Died December 20, 1916.

Although he never contributed to any scientific publication, Ernest Swain was well known to a past generation of geologists as a keen student of the science and a constant attendant at the meetings of the Geological Society and Geologists' Association. Of the latter he remained a member till the last.

He was born at Wood Lane, Shepherd's Bush, and educated privately and at King's College, of which he became an Associate. His life was passed in business in the West End, but all his spare time was devoted to scientific studies, and his museum and library were open to all friends and students, many of whom owed their start on a scientific career to his influence and aid. He was an active member of the quondam West London Scientific Association and the succeeding Western Microscopical Club. He devoted much time to the compilation of commonplace books, of which he kept some 140 going on the subjects that interested him. Unhappily he latterly met with bad times and retired to Chorley Wood, where he died at the close of last year.

[1] Professor of Mineralogy and Geology in the Polytechnic Institute, Sosnovka, Petrograd, Russia.

REGINALD COOKSEY BURTON,

B.Sc., F.G.S., Assistant Superintendent Geological Survey of India.

Born March 10, 1890. Died of wounds April 9, 1916.

The name of R. C. Burton has to be added to the "Roll of Honour" of geologists who have given their lives for their country in the present War.

Dr. H. H. Hayden, the Director, writes: "Mr. Burton joined the Department in January, 1912, and was posted to the Central Provinces, where, during his short period of service, he did admirable work in helping to solve the question of the origin of the calcareous gneisses which constitute such an important element of the Archæan group of that area. His investigations into the origin of the bauxite of Seoni and adjoining districts also gave evidence of marked ability, and by his death the Geological Survey has lost one of the most promising as well as one of the most popular of its younger members. Mr. Burton joined the Indian Army Reserve of Officers early in April, 1915, and after a short training in India was attached to the 104th Rifles in Mesopotamia, where he died on April 9, 1916, from wounds received in action on the previous day. His loss is keenly felt by all his colleagues." (Records of the Geological Survey of India, vol. xlvii, pt. iii, p. 143, August, 1916.)

SIR EDWARD BURNETT TYLOR, Knt.[1]

J.P., D.C.L., LL.D., F.R.S., Hon. Fellow of Balliol College, and Emeritus Professor of Anthropology, University of Oxford.

Born October 2, 1832. Died January 2, 1917.

This famous Anthropologist was born at Camberwell October 2, 1832, and educated at the school of the Society of Friends, Grove House, Tottenham, to which Society his family belonged. He was one of the sons of the originator of the old firm of Tylor and Sons, Brass-founders, Newgate Street, E.C., of which his brother Alfred Tylor, F.G.S., was for many years chief. Abandoning business E. B. Tylor devoted himself to the study of the races of mankind, their history, languages, and civilization, and had the advantage, at 24 years of age, to accompany his friend Henry Christy on a journey in Mexico in 1856; the archæological objects then collected now form part of the Christy Collection in the British Museum. His researches are embodied in *Anahuac, or Mexico and the Mexicans* (1861), *Researches into the History of Mankind* (1865), and *Primitive Culture: Researches into the Development of Mythology, Philosophy, Religion, Art, and Custom* (2 vols., 1871; 3rd ed., 1891). He was elected a Fellow of the Royal Society in 1871, Honorary LL.D. St. Andrew's (1873), and D.C.L. Oxford (1873). In 1883 he was appointed Keeper of the Oxford University Museum, Reader, and in 1896 the first Professor, in Anthropology. In 1858 he married Anna, daughter of the late Sylvanus Fox, of Wellington, Somerset. to which place he retired after resigning his post at Oxford. He received the honour of knighthood in 1912.

[1] See also *Nature*, January 11, 1917, p. 373.

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MARCH, 1917.

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2 GREAT FALLEN BLOCK OF LIPARITE, JAFNADAL.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. III.—MARCH, 1917.

ORIGINAL ARTICLES.

I.—A Remarkable Rock Stream in East Iceland.

By Leonard Hawkes, M.Sc., F.G.S.

(PLATE VI AND TEXT-MAP.)

IN his account of the volcanoes of Iceland, Thoroddsen describes two types of acid lavas which have been extruded in post-Glacial, prehistoric times. First are the lavas of the Torfajökull district, of the usual nature of acid flows, building up a compact mass of bluish-grey rock with an outer casing of obsidian and pumice. These lavas have been poured out in the post-Tertiary country, but the second type of stream is found most frequently in the older parts of the island, which otherwise have witnessed no volcanic eruptions since Tertiary times. This type of flow results from eruptions of a peculiar character in which "vast outflows of half-melted and unmelted masses of liparite, poured out from cauldron-shaped depressions, stretch down into the lowlands" (**1**, p. 503). The best example of these "Liparitische Blockströme" occurs in the Lodmundarfjord district, E. Iceland, and is especially described by Thoroddsen (**2**, pp. 159–161). In this paper the contention is put forward that the Lodmundarfjord blockstream is not a lava-flow but an unusual type of glacial moraine.

Unfortunately the magnificent topographical map of Iceland in preparation by the "Generalstaben" of Copenhagen does not yet include the Lodmundarfjord district, and no claim of special accuracy is made for the rough sketch-map of Fig. 3, which is given to render the description below more intelligible. The Lodmundarfjord, running approximately east and west, is bounded on both sides by ramparts of Tertiary plateau-basalts from two to three thousand feet in height. The fjord is continued inland in a broad flat valley, the Bárdarstadadal, and a raised beach, 23 metres high, after Thoroddsen (**2**, p. 103), shows that the sea formerly stretched far up the valley. The only notable breach in the southern wall occurs at 800 feet, the mouth of a broad hanging valley which forms part of the pass (the Hjalmadalsheiði, *circa* 2,000 feet) leading over to the Seydisfjord. On the north side, near the end of the fjord proper, a broad valley, the Hraundal, leads up from sea-level to the inland plateau in a north-westerly direction. The mountains of the Lodmundarfjord are built up exclusively of basalts and red tuff partings, but a thick series of acid rocks is exposed in the cliffs bordering the upper reaches of the Hraundal, being the southern extension of the largest area of acid rocks in Iceland. Especially noteworthy is the mountain Skúmhöttur, *circa* 3,000 feet high, into which a huge cirque extends. The cirque walls are very steep, falling to a broad gravelly plain about 750 feet high, over which a river—the Hrauná—meanders in a south-easterly direction till it cuts through a rise of about 50 feet, the beginning of the blockstream, and takes a rapid course through a gorge to the fjord. The blockstream is a chaotic assemblage of large angular blocks of liparite, a great number being twelve or more feet in diameter, with an extremely uneven hummocky surface, forming a wilderness known as the "Hraun".

"Hraun" is an old Norse word meaning "a rough place", "a wilderness", but in Iceland it came to signify "a lava field when

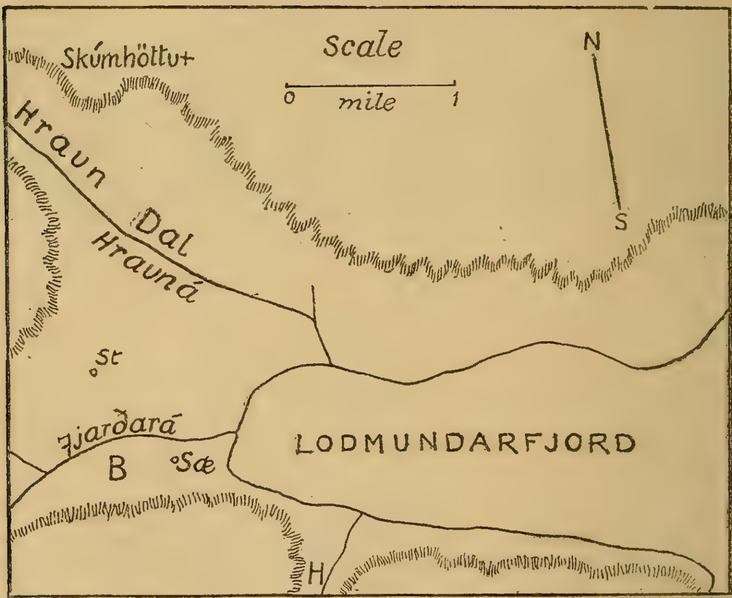

FIG. 3.—Sketch-map of the Lodmundarfjord District. H = the Hjalmadal; B = the Bárdarstadadal; Sæ = the farm Sæverendi; St = the farm Stakkahlið.

cold", "a burnt place", being so used in the Sagas as well as in modern times (**3**). Thoroddsen regards the blockstream as a lava-flow extruded from Skúmhöttur. The rough block surfaces of some acid lavas are well known and cited as a parallel, albeit the exceptional unevenness of the "Hraun" is taken as an indication that the lava was exceptionally viscous, and the daring suggestion is made that the liparite was first intruded into the Tertiary basalts and cooled down so slowly that when the plateau was dissected by dislocation and erosion the still hot magma flowed out as a stream of half-melted blocks (**2**, p. 161). A closer examination of the district reveals little to support this hypothesis. It is clear that the greater part of the material composing the "Hraun" comes from Skúmhöttur, but I am not satisfied that "the liparite is for the greater part intrusive here" (**2**, p. 276). The acid series is estimated to have a maximum thickness of 1,800 feet, and though the actual junction was covered with snow (June month) the basalts did not show any signs of disturbance commensurate with that to be expected if the main part of the series were intrusive. The acid rocks here are similar to those which the author has described from the neighbouring Seydisfjord (**4**, pp. 391–2), consisting of tuffs, breccias, obsidian, and liparite. One breccia underlying the main mass contains large fragments of liparite, pitchstone, and obsidian, and the farmer at Stakkahlið has some petrified tree trunks which were obtained here. Thus with proof of the extrusive nature of part of the series, and in the absence of indications of intrusion with the exception of some dykes, it seems probable that the main mass was extruded in Tertiary times, as is the case with so many occurrences of acid rocks in East Iceland (**5**, p. 468).

The chief objection to the hypothesis of a lava origin is the nature of the "Hraun" itself. Examination revealed the fact that the rock stream is not, as has been stated, exclusively composed of spherulitic liparite, but contains pitchstone, obsidian, pumice, and basalt. A beautiful mahogany obsidian is especially noteworthy, and all the rocks mentioned are to be seen in situ in the Skúmhöttur mountains. In the gorge of the Hrauná the "Hraun" is seen to be fragmental and composite to the base and to contain much gravelly material.[1] I saw no sign of a liparite dyke in the gorge, or any evidences of fumarolic action in situ as reported by Thoroddsen.

Perhaps the most interesting part of the rock stream, which is about one and a quarter miles in length, is its termination in the main fjord valley. Near the fjord the blocks become smaller until the final fan of fine fragmental material is reached, resting on the floor of the Bárdarstadadal, north of the Fjarðará. These deposits are seen in Pl. VI, Fig. 1. South of the river, at and to the west of Sæverendi, are a number of conical mounds commonly composed of liparite fragments, with obsidian and basalt less frequently. One of the largest mounds was elliptical in plan, 100 feet by 80 feet, with a maximum height of 23 feet, and contained a block of liparite 7 feet in diameter. Proceeding westwards the mounds become fewer and further between until about half a mile from Sæverendi the last one occurs close to the southern wall of the valley. Many of the mounds are exclusively formed of one type of rock, some of obsidian and others of liparite, and they furnish the clue to the problem of the origin of the "Hraun". Owing to its jointing

[1] In connexion with the lava hypothesis as advanced by Thoroddsen it is of interest to note that the block surface of some lavas in the Cordilleras of South America was taken by Humboldt and de Boussingault as evidence of eruption in fragmentary form, but Scrope considered this an "improbable hypothesis", pointing out that the fragmentary nature of lava streams is a property restricted to their upper and under surfaces, the main mass being compact (**6**, p. 70).

liparite commonly weathers out in very large blocks. A striking demonstration of this is to be found at the head of the Jafnadal, Stöðvarfjord, S.E. Iceland. The valley ends in a large cirque, the walls of which are chiefly composed of liparite. The plain about a thousand feet below the top of the cirque wall is dotted over with blocks of liparite which have rolled from above over the steep snow slopes. The largest of these blocks, measuring 90 feet by 45 feet by 40 feet, has split in two at its final resting-place (see Pl. VI, Fig. 2). The complete weathering down of such a block would give rise to a mound like the largest of those in the Lodmundarfjord valley. The mounds clearly result from the weathering of large blocks in situ, and the only agency which can be imagined to have brought them to their positions so far west is that of ice floating in the sea, which once stretched far up the valley as evidenced by the raised beach deposits. Thus the "Hraun" is of raised beach age and was not formed subsequently (**2**, p. 159), and it dates from the end of the last Ice Age, when the glacier of the fjord valley had retreated. The raised beaches along the fjords of the Folden district, Salten, N. Norway, are considered by Rekstad to be formed of morainic debris, and to date from the time when glaciers flowed down side valleys to the shores of the fjords (**7**, pp. 10–11). A similar explanation suffices for the deposits described in the Bárdarstadadal, and thus the "Hraun" is to be regarded as the moraine of a glacier flowing down Hraundal.

The morainic theory is rejected by Thoroddsen on two main grounds. These are (1) that "the whole mass of debris and blocks consist exclusively of one particular rock, spherulitic liparite, whilst a moraine must contain both", and (2) "no ice scratches are found on the blocks" (**2**, p. 160). As mentioned above, besides obsidian basalt does enter into the composition of the "Hraun", though to a remarkably small extent. This is partly understood when we consider the brittleness and fissility of liparite as contrasted with the toughness of basalt, whereby the former succumbs more easily to erosive agencies than the latter. The readiness with which liparite breaks up would itself account for the absence of ice-scratches on the blocks. During a field examination, extending over several weeks, of the acid rocks of East Iceland, the writer never saw an ice-scored surface of liparite.

I regard the "Hraun" as a surface "block-moraine", and it would not bear ice-scratches. The material probably did not fall slowly on to the glacier as a talus stream, but descended in great landslides, as has been suggested for some of the rock streams in the San Juan Mountains, Colorado, which are characterized by "the remarkable quantity of relatively coarse material comprising them, and the fact that the greater part of this must have been carried on the surface of the ice" (**8**, p. 25). The "Hraun" presents many analogies to the rock streams of the San Juan Mountains. These latter are comparable in size, the hummocky surface is similar, they are often composed of Tertiary acid volcanic rocks, and the topography of the district is that of a "dissected and glaciated plateau of more or less horizontally bedded volcanic rocks" (**9**, p. 11).

An interesting case of a landslide on to a glacier, which illustrates what has probably taken place in the formation of the "Hraun", is recorded by Freshfield from the Caucasus. "The Shikildi Glacier presented itself as an advancing mound of huge blocks of grey granite. . . . In 1866 a noise as of thunder was heard by the shepherds of the Baksan, and a great cloud of smoke or dust was observed to issue from the recesses of the chain under Ushba. . . . After a time it was ascertained that a great rock had crashed down from the cliffs on the east side of the Shikildi Glacier. . . . We saw next day the gap in the mountain side which had provided the enormous masses now strewn over the lower glacier. . . . I never saw such a goods-train of a glacier. . . . The immense size of the single blocks and the complete burial of the ice under them are the features which give their extraordinary character to the moraines of the Shikildi" (**10**, pp. 137–8). It is interesting to note that in the Saga relating the colonization of the Lodmundarfjord, *circa* 900 A.D., mention is made of a landslide, and whilst this cannot refer to the main mass of the "Hraun", there is little doubt that we here have evidence that sliding has taken place in historic times.[1]

Many of the San Juan rock streams are regarded as landslides which had no connexion with glaciers. It would be possible to regard the "Hraun" as such, and the mounds in the Bárdarstadadal as being formed from blocks transported by the shore ice-foot when this broke up. But apart from the fact that the general aspect of the "Hraun" is rather that of a moraine than a landslide, it is very probable that under the severer climatic conditions giving rise to an ice-foot, a glacier would exist in the Hraundal. Strictly the term "moraine" should be used only of material which has been actually transported by a glacier, rock debris which falls on to a stationary or retreating glacier being termed ordinary talus accumulations or landslide material according to degree. There will be cases which stand near the border-line between these two classes which will only be correctly placed after very careful investigation. Whilst reserving a final decision until the writer can make a more thorough examination, he is inclined to the opinion that the "Hraun" has been transported to some extent by a glacier and is therefore a true glacial moraine.

The rejection of the "lava-flow" hypothesis removes an exception to an important generalization, i.e. the post-Glacial instances of volcanic activity in Iceland are confined to the Quaternary Formation districts, so that the post-Glacial vulcanism is to be regarded as the direct continuation of the Quaternary and not the Tertiary activity (**12**, p. 18). It may be considered remarkable that the same

[1] "Lodmund the Old was the name of a man, and another was Beowolf his sworn brother. They came to Iceland from Thule-ness in Vors. Lodmund cast his porch-pillars overboard while he was at sea, and said that he would settle where they were drifted ashore. And the sworn-brethren made East-frith, and Lodmund took in settlement Lodmund-frith, and dwelt there three winters. Then he heard of his porch-pillars being in the south of the country. And with that he put on board his ship all that he had. . . . And when he had been a little while, there was a great rumbling noise, and they saw a great earth-slip fall upon the homestead which Lodmund had set up and dwelt in."—*Landnámabóc*, iv, 9 (**11**).

rock-stream should be regarded by one observer as a lava-flow and by another a glacial moraine, but a similar case is on record in the history of Icelandic geology. An accumulation of liparite blocks and debris in the Vatnsdal, Húnafjord, North Iceland, was thought by Schmidt to result from a post-glacial volcanic eruption (**13**, pp. 764–5), but it is now considered to date from the end of the Ice Age and to represent a great fall of rock on to a glacier (**2**, p. 271).

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EXPLANATION OF PLATE VI.

Fig. 1.—General view of the Lodmundarfjord "Hraun", looking north from Sæverendi. The Skúmhöttur cirque is seen in the middle background. The main fjord valley and the "Hraun" deposits north of the River Fjarðará occupy the foreground.

Fig. 2.—A great fallen block of liparite, now split into two, in the Jafnadal, Stöðvarfjord, East Iceland. A hammer may be distinguished on the face of the nearer block, not far from its base.

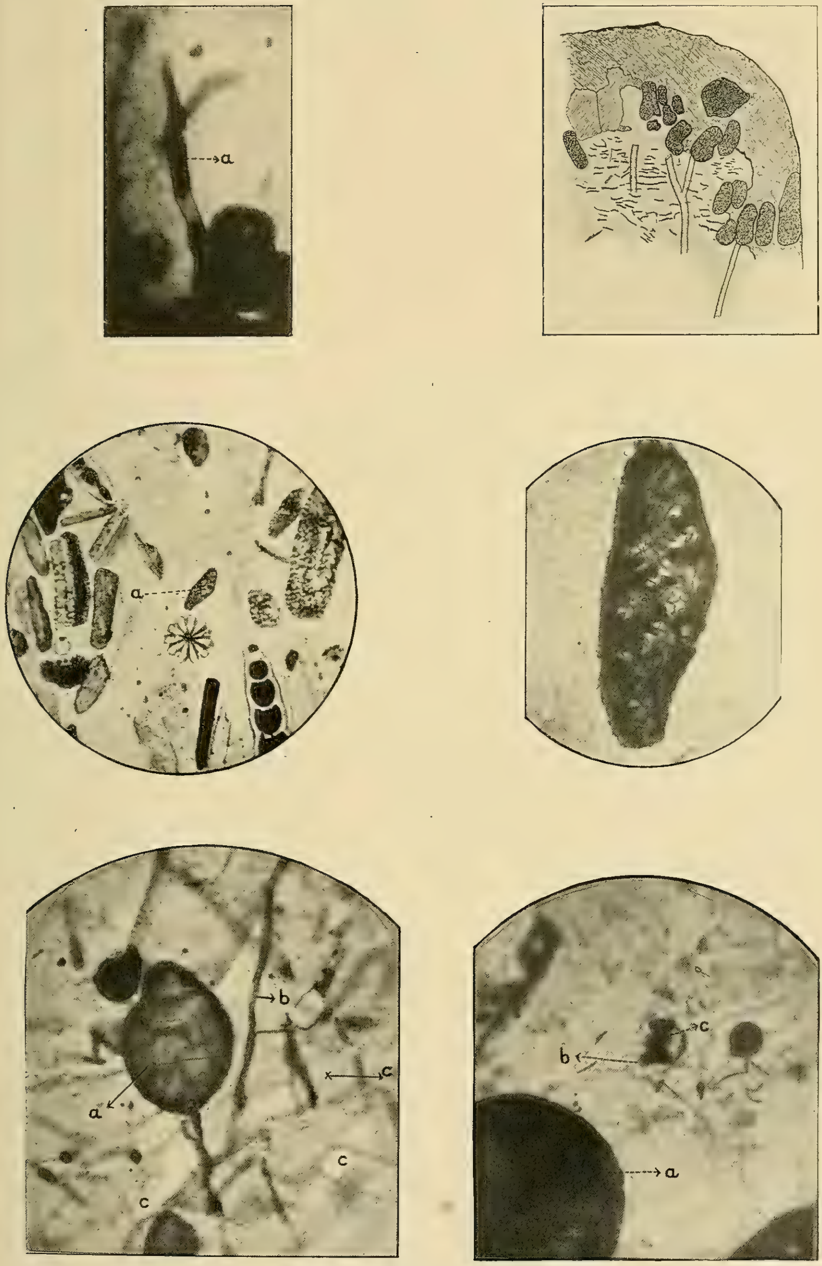
II.—On the Jurassic Fossil Fungus, *Phycomycites Frodinghamii* (Ellis).

By David Ellis, Ph.D., D.Sc.

(WITH PLATE VII AND A TEXT-FIGURE.)

In a recent paper[1] the writer described structures which he had found in the Frodingham Ironstone of Lincolnshire. The claim that these structures are fossil fungi is one of more than usual interest, for fossil fungi have not hitherto been recorded from the Jurassic rocks, and, further, the decomposition established by this fungus must have been carried out under marine conditions. Since the publication of this paper criticisms as to the conclusions contained in it have not been wanting, and it is proposed in the present paper to deal with these criticisms and further to furnish a few additional data to supplement those that have already been given.

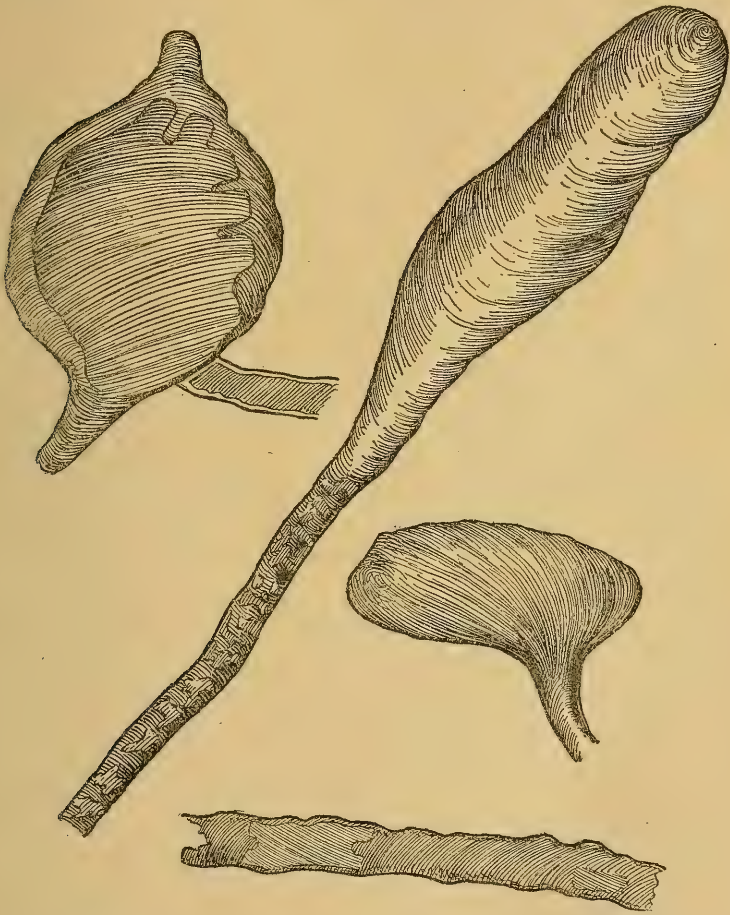
[1] "Fossil Micro-organisms from the Jurassic and Cretaceous Rocks of Great Britain": Proc. Roy. Soc. Edinburgh, vol. xxxv, pt. i, No. 10, 1915.



A JURASSIC FOSSIL FUNGUS.

Phycomycites Frodinghamii, &c.

Before dealing with the criticisms it must be borne in mind that the conclusions arrived at in the former paper were based on biological grounds. The structures were such as a biologist recognizes to be characteristic of fungi. They take the form of tubes coated with ferric oxide and conform to fungal structures in the following respects:—



Sketch of animal remains in Dunliath Ferruginous Limestone (Jurassic), N.W. Scotland, found in association with fungal hyphæ. × 1400.

1. The tubes are cylindrical and possess a membrane comparable to the membranes of modern fungi.
2. The diameter of the tubes is 2μ to 4μ ($\frac{1}{500}$ — $\frac{1}{250}$ mm.).
3. They branch and interweave in the manner characteristic of modern fungi. (In addition they also form whorled branches:

whilst not characteristic of modern fungi this feature is characteristic of other plants.)

4. They are uniform in size.

5. They form terminal dilatations which are comparable to the sporangia of modern fungi. This is particularly so with regard to their size as compared with the tubes which bear them, to their shape, and to their terminal position. In all respects they suggest the development of terminal reproductive organs on hyphæ (Pl. VII, Fig. 1).

6. In two instances, one of which is shown in Pl. VII, Fig. 2, rounded structures have been noted inside the terminal dilatations which in every essential particular suggest the spores which are formed inside the sporangia of modern fungi.

7. The structures in question are found in an organically formed rock (Pl. VII, Fig. 3).

The circumstantial evidence upon which alone the whole case naturally rests seems thus, from a biological standpoint, to be complete enough to allow of little doubt as to the matter. The points with which we shall now be dealing have had their inspiration in the minds of those accustomed to regard such matters more from the geological and mineralogical than from the biological standpoint.

1. *The structures in question may be of mineral and not of organic origin.*—Throughout the history of this subject mineral secretions have been repeatedly mistaken for organic remains. So far as the imitation of plant organs is concerned the structures imitated are leaves and cellular tissues. But from the nature of the case the plant patterns executed by these secretions are of a simple form and their variety of a very limited order. Whilst such secretions may imitate a cellular or a tubular structure, it is difficult to see how the whole atmosphere in which a phycomycetous fungus lives can be simulated so very faithfully by a mineral secretion that not only are hyphæ and hyphal membranes reproduced but also sporangia (Pl. VII, Fig. 1) and even spores (Pl. VII, Fig. 2). Further, the relative dimensional proportions of the parts are so faithfully adhered to that even when examined with the highest powers of the microscope, a trained eye cannot detect any details of structure inconsistent with the structural plan of phycomycetous fungi. Such wonderful fidelity in detail would demand strong evidence of an opposing nature to dismiss the claim that the structures in question are fossilized fungal remains. The slides have been submitted to several competent mineralogists for their opinion of the structures from the mineralogical standpoint. In no single case was evidence forthcoming to suggest that a mineral interpretation of these tubes and expansions would fit the facts of the case. Among those to whom the slides were submitted was Dr. Flett, of the Geological Survey, Edinburgh, whose opinion on this point will command respect. Dr. Flett stated that he was prepared to accept the organic origin of the structures indicated to him and that he knew of nothing in the mineralogical world that approximated to them. From the mineralogical standpoint no single positive fact has been brought to light which invalidates the claim for organic origin made from a study of the biological data.

2. *The structures may have been caused by insect borings.*—If the causation of these threads and vesicles is not to be ascribed to a mineral infiltration, and an organic origin is granted, there still remains another possible origin, viz. that the tubes were due to insect borings. This possibility has been suggested to account for the tubes and vesicles. This criticism would have weight were it not for the extreme smallness of the tubes. These measure only $\frac{1}{125}$ mm. In previous cases where this criticism had weight, as for example in the case of the *Rhizomorpha Sigillarieæ* of Lesquereux, the tubes under consideration were 2–3 mm. in diameter, and the claim was made that they were rhizomorphal cords of fungal hyphæ. Being commensurate in size with known insect borings, the criticism that they might have been produced by insects was quite legitimate. We are here, however, dealing not with cords of hyphæ, but rather with the individual strands such as are commonly found in the woody tissues of many plants. The possibility of their preservation need not be discussed, as their appearance in the tissues of fossil wood is too common and too well known to admit of any doubt on the matter. It is not conceivable that any insect either during Mesozoic times or at any time could make borings which simulated the biological characteristics of a fungus on such a minute scale. It is the more incredible when we reflect that these supposititious borings would be excavated in the body of some animal fragment, the natural habitat of many phycomycetous fungi, and not in the harder tissues of trees in which insect borings are usually found.

3. *Criticisms arising from the fact that whilst the parasite (or saprophyte) has been preserved the details of structure of the host in which it lived have not been preserved.*—In answer it may be stated that the discovery of this organism was not entirely due to an accidental circumstance, but was rather the successful issue of a specific search. In the author's researches on modern iron-bacteria, the membranes of which are impregnated with the highly resistant ferric oxide, he was led to the conclusion that if iron-bacteria or their representatives existed in former ages the chances of their preservation in fossil form were very strong. When the opportunity occurred ironstones and ferruginous limestones of various ages were carefully searched for iron-absorbing micro-organisms. The toughness and hardness of such membranes can be observed by anyone who cares to examine the dead membranes of the modern ochre-bacillus (*Leptothrix ochracea*). The search did not reveal fossil iron-bacteria as was expected, but it did bring to light a fungus possessing the same characteristic of absorbing iron-compounds from the surrounding water. An organism thus protected would obviously stand a much better chance of preservation than the soft tissues of the animal fragments inside which a fungus of this character must necessarily abide. The slides containing these structures consist of fragments of organic matter embedded in a calcite matrix (Pl. VII, Fig. 3). The threads and vesicles were invariably found inside the organic fragments and not in the matrix. An example is shown at *a* in Pl. VII, Fig. 3. This fragment is seen photographed on a higher scale of magnification in Pl. VII, Fig. 4. In the latter case the threads

under discussion are plainly revealed. It cannot be reasonably doubted that the fragment marked *a* in Pl. VII, Fig. 3, is an organic fragment similar to the other obviously organic fragments that are to be seen in the same field. It is unfortunate that in the Frodingham Ironstone in which these were found no traces of the internal structure of the animal host could be discerned, whilst the details of the structure of the parasite contained in it were so clear. This point, however, is capable of an easy explanation if it be assumed that the threads and vesicles represent a fossil fungus which *during its lifetime* had the same power of absorbing iron salts that the iron-bacteria possess at the present day. Under these circumstances the membranes of the fungus would be impregnated with ferric oxide during its lifetime, a circumstance which would render these membranes much more resistant to disrupting forces than the soft tissues in which they were embedded. Further, it is possible to conclude with a fair approach to certainty that the iron on the threads was laid down for the greater part during their lifetime. The reason for this conclusion is as follows: A study of the iron-bacteria has brought to light the fact that the deposit of iron on their membranes varies in consistency according to the age of the thread. Young threads have a sharply contoured membrane of a brownish-yellow colour. In older threads the nature of the deposition and of the membrane is quite different. The colour of the iron changes to a deeper brown, the quantity of it is greater, and the membrane, instead of being a continuous sharply outlined structure, is a discontinuous irregular line and wanting in sharp lines of demarcation. All gradations can be observed by a close study of the membranes of *Leptothrix ochracea*, the best known of the iron-bacteria. It is surely a significant fact that the same gradations can be observed on the membranes of the threads which we are now discussing. The appearance of these gradations is easily explicable if we assume that the tubes are the remains of an iron-absorbing fungus, but on the assumption that all the iron in these rocks, including the iron on these tubes, resulted from a subsequent infiltration of iron-charged water, the explanation is not so easy. It cannot be doubted that the bulk of the iron in these rocks arrived there by subsequent infiltration, but it is at least highly probable that some of it has never been absent from the material from which these rocks were formed. If the iron on these tubes had got there solely by infiltration, it would naturally be expected that all the tubes would have a deposit of a uniform nature; the tubes, on the other hand, show those changes which come about when iron enters the living cell, and after undergoing changes due to metabolism is thrust out again and deposited on the outer part of the membrane.

We may assume that the presence of the iron covering is a sufficient explanation of the preservation of these threads and vesicles. Whilst a search among the organic particles of the Frodingham Ironstone containing the fungus failed to reveal traces of the structure of the host, a measure of success was achieved by searching the similar Jurassic ferruginous limestone at Dunliath in the north-west of Scotland. In Pl. VII, Fig. 6, for example, we see an organic fragment showing traces of animal cells (*a*), and also a few hyphæ of some unknown fungus (*b*). Again, in others inside similar organic fragments structures like those represented in the Text-figure and in Pl. VII, Fig. 5 were met with. These are obviously the remains of some animal cells, although in this condition it is impossible to specify any further with regard to their nature. The point of the matter lies in this, that these organic fragments from Dunliath contain the remains of both animal cells and fungal threads, both very incomplete and very indefinite: in the Frodingham Ironstone the disruption of the animal cells has been complete, whilst the fungus, thanks to its protective covering, has been particularly well preserved.

4. *Doubts arising from the fact that the threads and vesicles were found in material known to have suffered decomposition in sea-water.*—Whilst it is true that no fossil fungi have so far been found of which it could be definitely stated that they had effected decomposition in salt water, the reason for this does not lie in the fact that there is anything inherently impossible in the idea, for that would imply that decomposition of organic matter cannot take place in salt water, which is contrary to experience. It is true that the vast bulk of marine decomposition is due to the activity of bacteria, but even in this field a large proportion of the organisms which carry on this decomposition belong to the sulphur bacteria, several species of which group are composed of long threads, thus approximating in their habits to the threads of which the aquatic fungi are composed. In the artificial cultivation of many of the thread-forming sulphur bacteria success attends the attempt only if sea water instead of fresh water be employed. A still more powerful argument is the fact that in the cultivation of some of the Saprolegnias, a group of phycomycetous fungi, the use of sea water is recommended in making up the nutrient medium. So that even in the case of modern plants of the same group we meet with fungal decomposition under marine conditions. Anyone who has studied the shores of Denmark can satisfy himself of the extent to which marine decomposition can operate in the scavenger work of Nature. The shallow Jurassic seas must have had huge shallow lagoons in which of necessity scavenger work on a large scale must have been in operation. It would be an extremely rash statement to assert even apart from our experience of modern fungi that no thread fungi could have contributed to this work. For even if such fungi did not exist at the present day, there are so many closely allied forms that effect decomposition in salt water that marine fungi in a fossil form would not have been a matter for surprise.

Conclusion.—The study of the tubes and vesicles classed under *Phycomycites Frodinghamii* had revealed their organic nature by the closeness with which their structures followed those of modern fungi. The resemblances extended even to minute points of structure, and were so great that from a biological standpoint no doubts were entertained as to the fact that we were dealing with fossil fungi allied to the modern Phycomycetes. It remained to inquire whether any positive evidence could be adduced, or any facts brought forward on mineralogical or geological grounds, which could impair the position taken up. The criticisms on theoretical grounds which have been brought forward have not invalidated the claim for these structures which the writer has brought forward. It is proposed to present the slides to the British Museum, so that they can be made available for inspection and reference.

EXPLANATION OF PLATE VII.

FIG. 1.—Frodingham Ironstone from Jurassic rocks of Lincolnshire. From interior of fossilized organic fragment. Shows hyphæ, one bearing a fully developed terminal sporangium. a=sporangium, b=hypha, c=calcite matrix. × 530.

„ 2.—Frodingham Ironstone from Jurassic rocks of Lincolnshire. Shows two sporangia of *Phycomycites Frodinghamii*. In the left sporangium (c), partially extruded from it, is seen a spore (b). a is a portion of a small oolite. × 166.

„ 3.—Organic remains in Frodingham Ironstone. At a is shown a fragment in which fungal hyphæ were found. × 18.

„ 4.—The organic fragment marked a in Fig. 3 shown on a larger scale. The fungal hyphæ are distinctly visible. × 116.

„ 5.—From Dunliath Ferruginous Limestone (Jurassic, N.W. Scotland). Remains of animal cells. × 466.

„ 6.—A semi-diagrammatic sketch of a portion of an organic fragment in the Dunliath Ferruginous Limestone. Inside the fragment are seen the remains of animal cells and of fungal hyphæ. The branched tubules are the hyphæ and the dark rounded fragment the animal cells.

III.—ON THE ORGANIZATION OF THE RUGOSE CORALS AND THE ORIGIN OF THEIR CHARACTERISTIC PECULIARITIES.

By Professor N. N. YAKOVLEV, Petrograd, Russia.

(PLATE VIII AND FOUR TEXT-FIGURES.)

DURING the last ten years I have published a series of memoirs [1] on different questions concerning the morphology and biology of the Rugose Corals. In these memoirs I have elucidated the ground-form of the polyparium of the solitary Rugosa, the mode of its attachment to the substratum, the origin of the characteristic arrangement of the septa, and the origin of the fossulæ in dependence on this form and attachment. I have established the connexion between the form of the polyparium of the Rugosa (including that of the fossulæ) and the life of these corals in definite environmental conditions.

[1] N. Yakovlev, "Die Fauna der oberen Abtheilung der palaeozoischen Ablagerungen im Donetz-Bassin. II. Die Korallen": Mém. Com. géol. St. Petersbourg, N.S., livraison xii, 1903. "A contribution to the Characteristic of Corals of the group Rugosa": Ann. Mag. Nat. Hist., ser. VII, vol. xiii, pp. 114–17, 1904. "Ueber die Morphologie und Morphogenie der Rugosa": Ver. Russ-k. Min. Ges. St. Petersbourg, vol. xli, pp. 394–415, 1904. "Die Entstehung der charakteristischen Eigentümlichkeiten der Korallen Rugosa": Mém. Com. géol. St. Petersbourg, N.S., livraison lxvi, 1910. "Les récifs coralliens existent-ils dans le paléozoique?": Bull. Com. géol. St. Petersbourg, vol. xxx, No. 10, pp. 847–57, 1911. "Studien über die Korallen Rugosa": Mém. Com. géol. St. Petersbourg, N.S., livraison xcvi, 1914.

Referring to the colonial Rugosa, I have explained how the characteristic forms of the colonies are correlated with the mode of multiplication, and demonstrated the part played by these corals in reef-building. Here and there I have pointed out differences between the Rugosa and the Hexacoralla, which do not admit the former to be considered as the progenitors of the latter, though this is probably claimed by the majority of palæontologists and zoologists.

This examination (pursued by me for many years) of the form and functions of the Rugose Corals and of the questions they raise, I now look upon as sufficiently complete to render desirable a review of the results of my work, which throws fresh light on the Rugosa as well as providing a causal explanation of the origin of the peculiarities of this specialized group. In conformity with the character of the present paper, the exposition will be given concisely, without citations and references, without criticism of other authors, without any details; those who are interested will find all this in my previous publications.

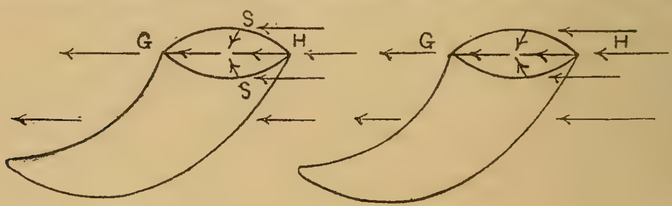
The shape of the Rugose polyparium is considered to be typically conical. Herein the Rugosa differ from the Hexacoralla, which mostly have a cylindrical polyparium; and this difference of body-form may be seen in the soft-bodied Actiniæ now living. The Rugosa are first found in Silurian rocks, but doubtless existed previous to this, and before Silurian times the Rugose polyparium had already departed from the fundamental simply-conical shape. *It had acquired*, near its proximal end, *a lateral attachment to the substratum*, unlike the basal attachment of the Hexacoralla (see Pl. VIII, Figs. 1–4). *This lateral attachment was correlated with their life in epicontinental seas.* The basal attachment of the cylindrical (or, in rare cases, conical) polyparium of the Hexacoralla living in deeper, calm water, as much satisfies the requirements of solidity as the lateral attachment of the Rugose conical polyparium living in a zone of the sea characterized by comparatively rough or at least agitated water.

The lateral attachment, then, of the Rugose polyparium is an adaptation to definite environmental conditions. It has modified the original form of the simply-conical polyparium and has imposed upon it a definite orientation correlated with the direction of the prevailing currents. For a conical polyparium lying on one side on the sea-bottom must of necessity turn away its mouth from the mud of the sea-bottom in order to avoid suffocation. Thus the simple cone with a straight axis becomes one with its axis curved in one plane—a form resembling the horn of an ox, and suggesting such trivial names as *cornu*, *corniculum*, *cornucopiæ*, *cornu-bovis*, *ceratites*, *buceros*, etc. Moreover, all the individuals of one locality were orientated in the same direction, namely, with their convex sides towards the direction of the prevailing current (see Text-fig. 1). Only thus will a polyparium of such a shape offer the maximum resistance to wave- and current-action tending to tear it from the substratum.

Now the scar formed by the attachment of the polyparium to the substratum as well as the root-like processes serving the same purpose necessarily occur as a rule on the convex side of the corallum.

And in this respect, as well as in its general form, the coral already shows an external bilateral symmetry. Scars of attachment and root-like processes, both on the convex side, and a general external bilateral symmetry, characterize all the known Rugosa from the Silurian rocks, the earliest in which they have yet been found, to the Permian in which the last Rugosa occur. Further, when, owing to the character of the sea-bottom, there is no possibility of attachment and the coral consequently is free, the polyparium, whether of a Rugose or Hexa-coral, takes on a flat, discoid shape (*Palæocyclus*, *Microcyclus*, etc.). But, in spite of its not leaning over, the Rugose Coral retains its bilateral symmetry, shown externally chiefly by the apex which lies excentrically, while that of the Hexacoral is central. That is to say, in spite of the removal of the conditions producing bilateral symmetry, the discoid Rugose Coral exhibits it. Is not this an example of the inheritance of acquired characters?

Another form showing the tendency to retain bilateral symmetry after the conditions which caused it have been removed is that taken by unattached genera such as *Calceola*, *Platyphyllum*, and other operculate corals. These are curved, flat on the lower side, and

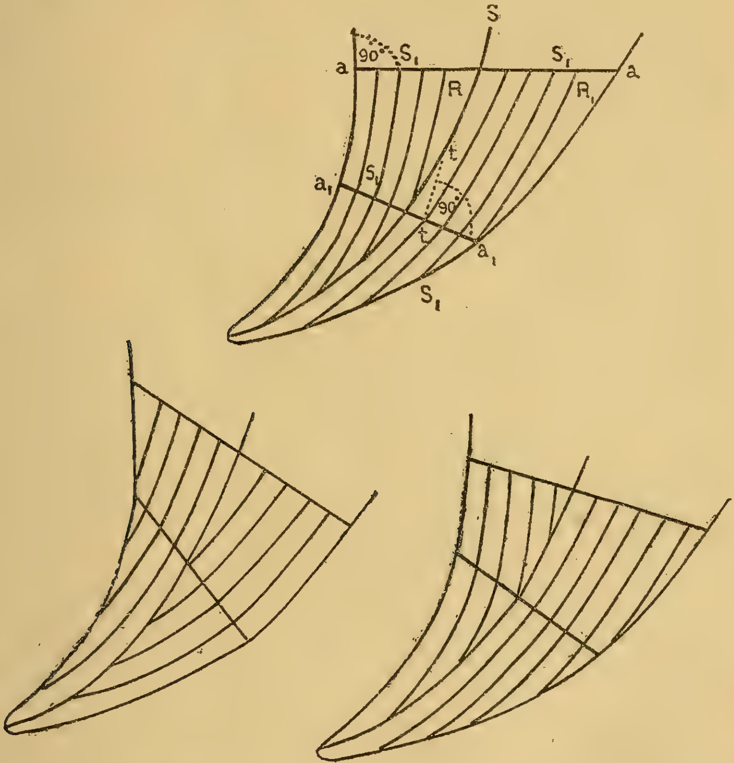


TEXT-FIG. 1.—Diagram representing two polyparia of solitary Rugosa growing side by side. The arrows outside the polyparia indicate the direction of the prevailing current, and those within the calices that of the water along the channels formed by the fossulæ. *H*, *G*, *S*, the positions of the Main, Counter, and Alar fossulæ respectively. Nat. size.

provided with an operculum whose function is to prevent the penetration of mud into the coral's calice. Operculate corals are probably polyphyletic in origin, and, as would be expected, occur only among the Rugosa.

The last external character dealt with is the frequently occurring phenomenon of "Rejuvenescence". The term is inappropriate, since young individuals also are subject to it. Rejuvenescence consists of a periodically repeated retraction of the calice as if by shrinking or by the appearance of a daughter coral produced by intracalicinal budding. Rejuvenescence, especially in the broadly conical forms, is easily explicable, in fact only to be expected, when it is considered how inconvenient and disadvantageous from a mechanical point of view a considerable upward expansion of the polyparium would be to the Rugosa with their typically conical polyparium.

Turning from the external to the internal characters of the Rugose skeleton, we shall find that they are determined by the curved condition of the conical polyparium. We shall consider, first of all, the characteristic arrangement of the secondary septa and their relation to the primary septa—a condition peculiar to the Rugosa. The works of Duerden, Carruthers, and others have shown that the secondary septa develop in four adjoining (and in four only out of six) primary interseptal chambers, and are bilaterally symmetrical in their arrangement. Two of the primary septa lie in the plane of bilateral symmetry of the coral. About one of these—the Main-septum—the secondary septa (as seen at their outcrops on the wall



TEXT-FIG. 2.—Diagram showing the arrangement of the outcrops of the septa on the surface of the polyparium, according to whether the mouth is at right angles to the concave side (above), to the convex side (below, on the left), or to neither (below, on the right). The mouth is always at right angles or nearly at right angles to the Counter-septum. *S*, Alar-septum. *aa*, *a'a'*, the edges of the polyparium at different periods of its growth. (After Yakovlev, 1904.)

of the polyparium) are arranged pinnately; while on each side of the other—the Counter-septum—the secondary septa lie parallel both to it and to each other (see Text-fig. 2). Two other primary septa—the Alar-septa—lie somewhat at right angles to the Main- and Counter-septa, thus dividing the calice into four quadrants, two Main- and two Counter-quadrants. As seen at their outcrop on the wall of the polyparium, the secondary septa are pinnately arranged with regard to the Alar-septa in the Counter-quadrants and lie parallel to the Alar-septa in the Main-quadrants (see Text-fig. 2 above).

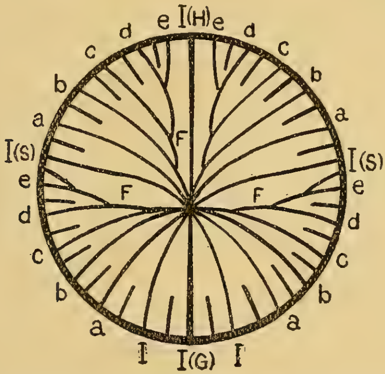
Such an arrangement of the secondary septa appears to be the natural outcome of the mechanical conditions imposed by the curved state of the conical polyparium. For the mouth of the conical polyparium is generally in a plane perpendicular to its concave side (Text-fig. 2 above); and the secondary septa have a tendency to grow (as in all Anthozoa) in a plane perpendicular to that of the mouth of the calice. Since the primary septa are already existent in a curved polyparium, the secondary septa can grow in a manner just stated, and unimpeded, in two only of the four Primary quadrants, namely in the two Counter-quadrants. In the two other quadrants, namely the Main-quadrants, the secondary septa cannot grow in a plane perpendicular to that of the mouth, because, at least in part, they would be impeded by the convex surface of the Alar-septa (see the dotted line *t-t* in Text-fig. 2 above). Therefore they grow, as may be observed, so that their outcrops on the coral-wall are parallel with those of the Alar-septa.

But the Main-septum, sometimes, though comparatively rarely, lies on the *concave* side of the coral. When this is so, the plane of the mouth of the calice is perpendicular to the *convex* side of the coral (see Text-fig. 2, below and on the left). Applying to this case the principle that the secondary septa tend to lie at right angles to the plane of the mouth, we see that they can only thus grow unimpeded in the quadrants lying on the *convex* side of the coral (now the Counter-quadrants), whilst in the other pair of quadrants the growth of secondary septa perpendicular to the plane of the mouth would be impeded by the concave face of the Alar-septa.

A third, intermediary type also occurs (Text-fig. 2, below and right-hand side) in which the plane of the mouth is inclined approximately equally to the convex and concave side of the polyparium. In this case the Main-septum occurs on the convex side of the coral as it did in the first instance.

The fossulæ arise as a necessary consequence of the primate arrangement of the secondary septa. For there is always a comparatively broad space left between the youngest secondary septa and the Main-septum in the two Main-quadrants, and between the youngest secondary septa and the Alar-septa in the Counter-quadrants (R, R_1 of Text-fig. 2 on the left) into which the soft tissues settle down and contribute to the widening of these spaces, converting them into permanent cavities. These spaces are the Main- and the Alar-fossulæ. The Main-fossula placed on the convex or concave side of the corallum, according to the position of the Main-septum, is really two juxtaposed fossulæ, but appears as one, because of the shortness of the Main-septum. Consequently it is wider than the Alar-fossulæ and is more constantly conspicuous than these. The shortness of the Main-septum is caused by the soft tissues settling down into the Main-fossula. This sagging of the soft tissue, pressing also against the sides of the fossula, caused the deviation of the free edge of the secondary septa towards the one preceding it, so as, finally, to fuse with it (*a* with S_1 and *I*, and *b* with *a*, in Text-fig. 3), giving the appearance (it is, of course, only an appearance) of repeated branching of the primary septa. The septal fusion occurs in young individuals as well as in mature ones. The older parts of many polyparia become cylindrical and straight instead of conical and curved. In these there are no wide spaces between the primary and secondary septa, and consequently there is less development of the fossulæ, and the fusion of the septa disappears—in a word, radial symmetry, doubtless existent in the progenitors of the Rugosa, is re-established.

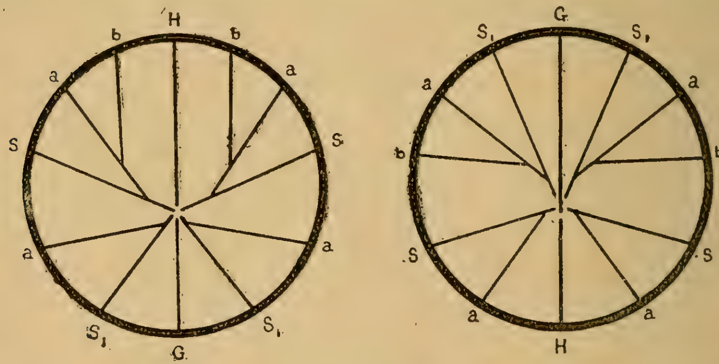
Since the fourth fossula, that lying on each side of the Counter-septum, is rarely visible in the Rugose skeleton, its origin must be different from that of the other fossulæ. Its presence is due to the fact that there are no secondary septa adjacent to the Counter-septum. A study of the functions of the other fossulæ (of course



TEXT-FIG. 3.—Diagram of the calice of *Hadrophyllum pauciradiatum*, Edwards & Haime. *H*, *G*, *S*, Main, Counter, and Alar septa respectively. *a–e*, secondary septa. *F*, *F*, *F*, Fossulæ. (After Duerden, 1905.) Nat. size.

a purely hypothetical consideration, dealing, as it does, with the soft parts of an extinct group of animals) may help to explain the origin of the Counter-fossula. It appears to me that the function of the Main- and Alar-fossulæ was to bring water to the axial part of the coral. This is partly corroborated by the fact that all three lie in one general direction, since the Alar-septa make an acute angle with the Main-septum. I have established the hypothesis that the solitary, curved polyparia of the Rugosa, during their life, were orientated on the sea-bottom with their convex sides towards the prevailing currents, a position most advantageous from a mechanical point of view (see Text-fig. 1). This orientation itself would cause the water to flow along the Main- and Alar-fossulæ towards the axial parts of the coral; and the water would naturally find its exit on the opposite side, namely along the Counter-fossula, which doubtless arose for this purpose. For, though not constantly expressed in the skeleton, the Counter-fossula would then be too important not to be constantly expressed in the soft parts of the coral. If this were so, the presence of the Counter-fossula in the soft tissues might actually impede the formation of secondary septa in the loculi adjacent to the Counter-septum (Text-fig. 4).

A last peculiarity of the solitary Rugosa correlated with the curved, conical polyparium, is the fact that the number of secondary septa present in the quadrants on the convex side, is sometimes greater than the number of secondary septa on the concave side (Text-fig. 4). Consequently, the position of the axis of the coral, as defined by the point of meeting of the primary septa within the polyparium, appears displaced towards the polyparium's concave side. This phenomenon is no doubt due to retardation of development on the concave side, as though under the influence of contraction of the coral here at its curved part; on the convex side, on the other

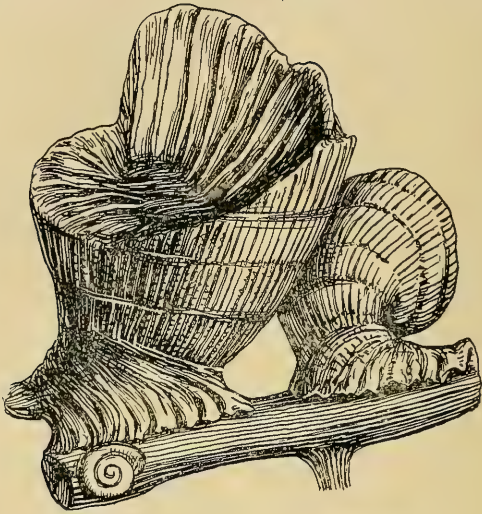


Text-fig. 4.—Diagrammatic sections of *Lophophyllum proliferum*, McChesney. The section on the left is a Russian and on the right an American specimen. In both cases the upper side of the section is on the convex side of the polyparium (after Yakovlev & Duerden, 1903). *H*, *G*, *S*, Main, Counter, and Alar septa respectively. S_1, the fourth pair of primary septa. *a*, *b*, secondary septa. $\frac{4}{5}$ nat. size.

hand, the development is accelerated, as though under the influence of distention.

Colonial Rugosa are characterized by intracalicinal budding, resulting in a bush-like appearance, and causing a limited growth of the colony. Hexacorals, on the other hand, multiply by division and build colonies which spread far from their initial point on the surface of the substratum. Colonial Rugosa also differ from Hexacorals in the greater size of their individual corallites. The Rugosa, consequently, do not possess the plasticity necessary for producing the variety of colonial forms that we find among the Hexacorals, e.g. *Madrepora*. To the small dimensions of the colonies and to the monotony of form probably was due the small share they took in building Palæozoic reefs.

The Rugosa became extinct at the close of Palæozoic time, probably in consequence of an unfavourable environment, which may have



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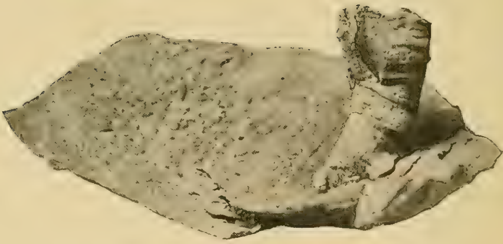

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LATERAL ATTACHMENT OF RUGOSE CORALS.

been due to the following causes. The end of Palæozoic time coincides with a worldwide period of mountain-building—the period of the so-called Appalachian revolution of American authors, and that of the building of the Ural and Donetz ranges of Russia (where the change of facies is surprisingly abrupt—the limestone strata of the Upper Carboniferous giving way to the Permo-Carboniferous characterized by great expanses of sandstones). When the limestones, laid down in shallow and comparatively calm waters, were deposited, the environment was favourable to the life of Rugosa Corals. But the mountain-building uplifts, causing great quantities of clastic material removed by denudation to be brought down and deposited in the sea, created conditions the reverse of favourable to the corals. In the Permo-Carboniferous the Rugosa are already rare, and after that time are extinct; and nearly the same fate befel the Tabulate corals. When suitable conditions again arrived, a new race of corals arose—the Hexacorals—replacing the Rugosa.

The above explanation of the organization of the Rugose Corals results from considering the simple primary factors of morphogenesis. I think that it is only for such simply organized animals as the Cœlenterata that such a complete and harmonious explanation is possible; and that it is not possible to give an all-embracing expression, reduced to a mathematical formula, of the structure of higher animals, because of their complex organization. In a few cases, however, such expressions have been found for isolated organs of higher animals; for instance, in the case of the development of the feet and teeth of Vertebrates.

EXPLANATION OF PLATE VIII.

The Lateral Attachment of Rugose Corals.

Fig. 1.—*Cyathophyllum ceratites*, Goldfuss, attached to a branch of *C. cæspitosum*, Goldfuss. Devonian: Timan Range, River Uchta.

,, 2.—*Pseudocaninia conica* (Fischer de Waldheim), attached to a spine of *Archæocidaris*. Upper Carboniferous: Mjatshkovo village, Government of Moscow.

,, 3.—*Petraia permiana*, Nechaev, attached to the dorsal valve of *Strophalosia*. Permian: Gorodistshe village, Government of Vjatka. A. V. Nechaev's specimen.

,, 4.—*Cyathophyllum heterophyllum*, Edwards & Haime, attached by a highly developed, sole-like appendage. Devonian: Paffrath, Rhenish Prussia.

IV.—A Mineralogical Classification of Igneous Rocks.

By Arthur Holmes, A.R.C.S., D.I.C., B.Sc., F.G.S.

During the past two years the teaching collection of rocks in the Geological Department of the Imperial College has been under re-arrangement, and in the course of the work the writer has had occasion to consider very carefully the principles on which igneous rocks should be classified. He is aware that in the present state of our knowledge any such classification must be tentative and experimental, and should be judged according to its general convenience, both for teaching purposes and for understanding the various problems that arise from petrological studies. The following article summarizes the conclusions arrived at, and while the writer must be held entirely responsible for all expression of opinion, he wishes to acknowledge his gratitude and indebtedness to Professor Watts and Dr. Evans, both of whom, in numerous discussions, have freely offered suggestions and criticism which have proved to be of the greatest value.

In recent years the chief criteria on which systematic classifications of igneous rocks have been based are (*a*) mineral composition, (*b*) chemical composition, and (*c*) texture, or (*c*′) mode of occurrence (Cross, 1910, p. 473). Although the two latter factors have often been considered interdependent, it is now becoming generally recognized that they are by no means wholly so, and modern custom tends more and more to relegate each of them to a subsidiary position in classification. For the working petrologist, the mineral composition of an igneous rock is, in a great majority of cases, its most important characteristic. Unfortunately, many minerals, such as the pyroxenes and amphiboles, are capable of a wide range in composition. Moreover, a small percentage of igneous rocks are incompletely crystallized. It has therefore to be recognized, and accepted as at present an unavoidable limitation, that the *whole* field of igneous rocks cannot be reliably classified on a mineralogical basis that will also faithfully reflect the chemical composition. On the other hand, a chemical classification, whether founded on normative minerals, or otherwise, demands far more analyses than can in practice be obtained. In addition to the requirements of field-work, it is therefore necessary to have at least two systems of classification, one mineral, the other chemical. Clearly, for purposes of comparison, the two systems should be arranged as closely as possible along parallel lines.

In the Quantitative Classification of Cross, Iddings, Pirsson, and Washington, the chemical composition is expressed, not in oxides, but by a series of standard minerals known as the *norm*, as opposed to the *mode*, which is the actual mineral composition. The first division, into *Classes*, is based on the relative proportions of the *salic* and *femic* groups of minerals in the norm (corresponding terms for the mode are *felsic* and *mafic*). As Mr. G. W. Tyrrell (p. 63) has pointed out, the five classes that are adopted correspond in principle, though in greater detail, to Brögger's division of igneous rocks into leucocratic and melanocratic types.

The second division, into *Orders*, is based in the first three classes on the ratio of quartz, or if quartz be absent of felspathoid, to felspar. The orders thus correspond partially to Professor Shand's division of igneous rocks into oversaturated, saturated, and undersaturated types (1913, p. 513, and 1915, p. 340). One of the most serious defects of the C.I.P.W. Classification, to which attention was drawn by Tyrrell in 1914 (p. 68), lies in the fact that the method of subdivision into orders in Classes IV and V is based on ratios of the femic minerals, thereby introducing a most confusing break and lack of parallelism between the subdivisions of Classes I to III, and those of IV and V. Tyrrell urges that the salic divisions should be carried on through all the classes, and for the same reason the femic divisions of the later classes might, if desired, be carried back through the early classes, thus providing each rock analysed with a double symbol.

It also seems to the present writer that Order 5, embracing as it does rocks with normative quartz and felspar, felspar alone, or felspar and felspathoid, is of too broad a character. It traverses one of the few natural lines of distinction available for classification, the line between the antipathetic minerals quartz and felspathoid. Certainly the norm indicates which of these is present, but in the symbol it might advantageously be expressed by suffixes such as the following:—

5*q* (accessory normative quartz present),
5 (no quartz nor felspathoid present; in this case normative olivine would generally be present),
5*l* (accessory felspathoid, or lenad, present).

The division of orders (of Classes I to III) into *Rangs* is based on the ratio of the molecular proportions of alkalies to lime, only those entering into the salic minerals being employed for comparison. Mineralogically, this is practically the ratio of orthoclase plus albite to anorthite, it being understood that felspathoids, where present, are to be expressed in terms of the amounts of orthoclase and albite to which they are equivalent. The ratio, however, tells us very little about the rock to which it is applied beyond expressing in a general way its alkalic or calcic character. It is suggested below that a more useful method of division would be afforded by the ratio of the molecular proportions of soda to lime in the felspars, or better, of the direct ratio by weight of albite to anorthite. Such a ratio would express the normative soda-lime felspar, and in many cases the latter would not materially differ from the actual soda-lime felspar of the rock.

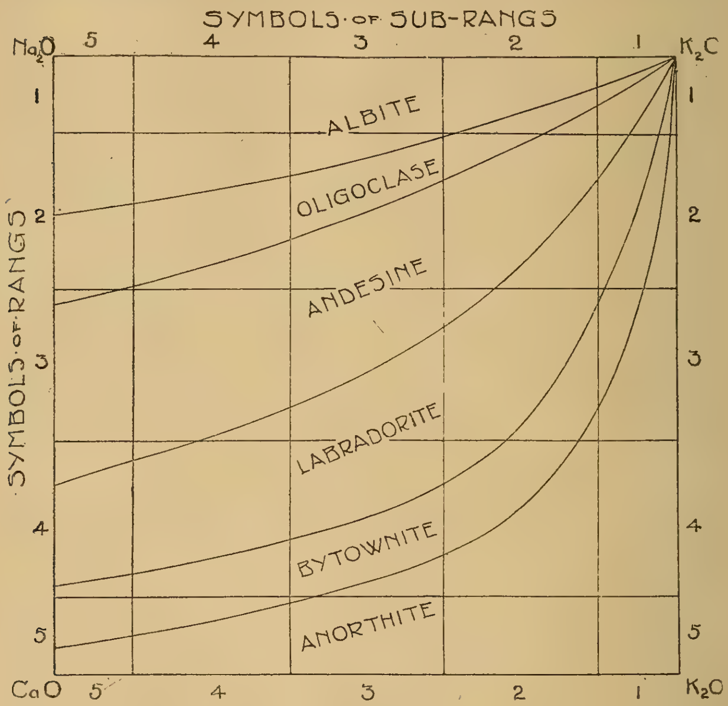
The division of rangs into *Sub-rangs* is based on the molecular ratio of salic potash to salic soda, and is useful in distinguishing rocks with minerals like orthoclase, muscovite, leucite, and biotite, from those containing albite, analcime, nepheline, etc.

It has frequently been a matter for surprise that the sub-rangs of the C.I.P.W. Classification (of which in the first three classes there are 675) do not always contain rocks of closely similar types, and that adjacent sub-rangs may sometimes enclose rocks that are much more closely related to one another than they may be to other rocks falling within their own sub-rang. The latter possibility is illustrated by the following analyses, taken from Iddings' *Igneous Rocks*, vol. ii:—

	A.	B.	C.	D.	E.
SiO_2 .	75·04	75·17	74·37	73·05	64·57
Al_2O_3 .	13·12	12·66	13·12	14·67	16·80
Fe_2O_3 .	2·12	0·23	0·73	0·89	0·97
FeO .	n. d.	1·40	0·87	n. d.	3·02
MgO .	0·34	0·05	0·35	0·26	1·69
CaO .	0·40	0·82	1·26	0·97	3·53
Na_2O .	2·44	2·88	2·57	3·99	3·81
K_2O .	6·32	5·75	6·09	5·11	4·01
H_2O .	0·76	0·82	0·30	0·91	1·28
Incl. .	—	0·47	0·45	—	—
Total .	100·54	100·26	100·11	99·85	99·68
Symbol :	I, 4, 1, 2 Omeose.	I, 4, 1, 3 Liparose.	I, 4, 2, 3 Toscanose.	I, 4, 2, 3 Toscanose.	I, 4, 2, 3 Toscanose.

A.	Felsite porphyry;	Varese, Piedmont.
B.	Granitite;	Pikes Peak, Colorado.
C.	Granitite;	Crazy Mts., Montana.
D.	Obsidian;	Teneriffe, Canary Islands.
E.	Toscanite;	Bracciano, Italy.

A, B, and C, falling in adjacent sub-rangs, bear a much closer resemblance to one another than do C, D, and E, all of which fall in the same sub-rang.



In the above diagram the rectangular spaces represent subdivisions of the C.I.P.W. Classification formed by rangs and sub-rangs. The spaces between the curved lines represent the distribution of the different soda-lime felspars across the C.I.P.W. Classification in Classes I–III, Orders 1–4 and part of 5. In the case of other orders, the curves occupy other positions which may be obtained approximately by swinging them upwards about the north-east corner through an angle depending on the amount of felspathoid present in the norm.

Actually, the classification is, as generally used, in four dimensions, and consequently sixteen sub-rangs meet in the theoretical point determined by the intersection of four super planes. Thus it would be possible for sixteen closely similar analyses to fall into sixteen adjacent pigeonholes, whereas sixteen analyses distributed evenly through any one of the pigeonholes would show considerably more variation. Obviously, this is not a serious fault in the classification unless it can be shown that there is a natural grouping of rocks. If there were, and the existing modal nomenclature is

I.

OVERSATURATED ROCKS: CHARACTERIZED BY QUARTZ.

Or_0 SODA $Or_{12\cdot5}$ ROCKS. $Or_{37\cdot5}$ SODA-POTASH ROCKS. $Or_{62\cdot5}$ POTASH $Or_{87\cdot5}$ ROCKS. Or_{100}

ALBITE.	SODA-GRANITE. Rockallite. PEGMATITE. SODA-QUARTZ PORPHYRY SODA RHYOLITE. Comendite and Pantellerite.	SODA-POTASH GRANITE. Ekerite. Grorudite. PEGMATITE. SODA-POTASH Q. PORPHYRY Quartz bostonite. Paisanite. SODA-POTASH RHYOLITE.	POTASH-GRANITE. Muscovite granite. Muscovite biotite granite. PEGMATITE. Granophyre. POTASH QUARTZ PORPHYRY. Aplite. POTASH RHYOLITE.
An_{15}			
OLIGOCLASE-ANDESINE.	QUARTZ-DIORITE. Tonalite. | GRANO-DIORITE. QUARTZ PORPHYRITE. DACITE.	ADAMELLITE. Quartz monzonite. RHYO-DACITE. Quartz latite. Dellenite.	GRANITE. Biotite-granite. Hornblende granite. Augite granite, etc. PEGMATITE. Granophyre. QUARTZ PORPHYRY. Nevadite. Aplite. RHYOLITE. Liparite.
An_{50}			
LABRADORITE-ANORTHITE.	QUARTZ GABBRO. Quartz anorthosite. Quartz norite. QUARTZ DOLERITE. Quartz diabase. QUARTZ BASALT. Bandaite.	QUARTZ MONZONITE (in part). QUARTZ TRACHY-DOLERITE.	Labradorite granite.
An_{100}			
Felspar absent or accessory.	QUARTZ PYROXENITE. Quartz hornblendite.		

based on the assumption that there are at least a few such groupings, then instead of fitting them into ready-made compartments the divisions of a satisfactory classification should be drawn around them.

The other feature, to which many criticisms have been directed (e.g. Evans, p. 270; and Harker, *Natural History of Igneous Rocks*, pp. 363–4)—that widely different types of rocks may fall into the same sub-rang—is due partially to the dependence of names on textures, and partially to incorrect applications of the modal nomenclature, much of which, it must be confessed, is unnecessarily vaguely defined. Some glaring examples are exposed in vol. ii of Iddings' *Igneous Rocks*: e.g., "an olivine diabase" with 10·7 per cent normative quartz (p. 144); a "hornblende granite" with 56·8 per cent labradorite and only 7·2 per cent of orthoclase (p. 146); and a "basalt" with 40 per cent of nepheline and leucite and no soda-lime felspar (p. 306).

The relation of the rang classification of soda-lime felspars to those already in use is shown by the following figures, which express the percentage of anorthite in each case.

Soda-lime Felspars.	Tschermak.	Adapted from Day & Allen.	Rang Divisions.	No. of Rang.
Albite	0–11	0–15	0–7	1
Oligoclase	14–33	15–25	7–25	2
Andesine . . .	40–43	25–50	25–47	3
Labradorite . . .	50–67	50–75		
			47–78	4
Bytownite . . .	75–86	75–85		
			78–100	5
Anorthite . . .	86–100	85–100		

Another reason for the lack of similarity between the rocks of certain sub-rangs, and one for which the C.I.P.W. Classification is itself wholly responsible, is displayed in the diagram on p. 118. In this, the subdivisions formed by rangs and sub-rangs are drawn to scale, and across them the distribution of the different soda-lime felspars is plotted. In most cases it will be noticed that two or three, and in a few others even more, of the recognized varieties of plagioclase are present within a single compartment. In Toscanose, for example (I, 4, 2, 3), the felspar may be albite, oligoclase, or andesine, and it is precisely this sub-rang to which attention has been directed by Harker (pp. 363–4) as exemplifying the extraordinary degree of non-parallelism between modal and normative classifications. Since in the former the kind of soda-lime felspar is often an important diagnostic, it was an inevitable consequence that the latter, as arranged in its present form (in which the co-ordinates of rang and sub-rang are not independent of each other), should traverse the older nomenclature in an unnatural way. For this reason it is suggested for consideration by the authors of the Quantitative Classification that the molecular ratio of salic alkalies to lime should be replaced by the molecular ratio of felspathic soda to lime. If this were done, each component of the magmatic symbol would convey a definite mineralogical meaning, and rocks having the

II.

SATURATED ROCKS.

Or_0 SODA $Or_{12\cdot5}$ ROCKS. $Or_{37\cdot5}$ SODA-POTASH ROCKS. $Or_{62\cdot5}$ POTASH $Or_{87\cdot5}$ ROCKS. Or_{100}

	Soda	Soda-potash	Potash
ALBITE.	SODA AND SODA-POTASH SYENITES. Albitite. SODA AND SODA-POTASH PORPHYRIES. SODA AND SODA-POTASH TRACHYTES. Keratophyre and Pantellerite-trachyte.	Laurvikite. Nordmarkite. Pulaskite. Bostonite. Sölvsbergite.	POTASH-SYENITE. POTASH PORPHYRY. Minette (in part). POTASH TRACHYTE.
An_{15}			
OLIGOCLASE-ANDESINE.	DIORITE. / SYENO-DIORITE. PORPHYRITE. Malchite. ANDESITE.	MONZONITE.[1] Oligoclase-syenite. Andesine-syenite. Akerite. MONZONITE PORPHYRY. Mænaite. Vogesite and minette. TRACHY-ANDESITE. Latite. Vulsinite.	SYENITE. PORPHYRY. TRACHYTE.
An_{50}			
LABRADORITE-ANORTHITE.	GABBRO. Anorthosite. Norite. Hyperite. DOLERITE. Diabase. Spessartite and kersantite. BASALT. Tholeiite.	LABRADORITE-MONZONITE. MONZONITE-PORPHYRY. Gauteite. TRACHY-DOLERITE.	Labradorite syenite.
An_{100}			
Felspar absent or accessory.	PYROXENITE. Hornblendite. AUGITITE.		

[1] The name 'Monzonite' as a specific name stands in urgent need of limitation and redefinition. It is given here according to the usage adopted by Brögger, although it should certainly be limited to rocks with a soda-lime felspar at least as calcic as andesine, if not labradorite. The very broad American usage of the term is particularly unfortunate.

same symbol would be much more closely akin than is at present the case. If no normative felspar were present, the rang symbol could be omitted, and the sub-rang symbol would then express the kind of felspathoid in the rock. A fivefold classification of the soda-lime felspars by the rang method would probably be equally as good as the sixfold classification usually adopted.

A natural line of division, similar to that employed to separate quartz-bearing from felspathoid-bearing rocks, may be drawn between quartz-bearing and olivine-bearing rocks.[1] To express the presence of olivine in the norm of a rock the number corresponding to the ratio of pyroxene to olivine (section of grad) might be added to the symbol. As an example of the kind of normative symbol here advocated, the following may be taken: II, 5_l, 4, 4, 1. The characters of the rock could then be read off immediately:—

II signifies that salic minerals are dominant;
$5l$,, ,, felspathoid is accessory;
4 ,, ,, labradorite is present;
4 ,, ,, soda is dominant over potash;
1 ,, ,, pyroxene is dominant over olivine.

Clearly the rock would be an olivine-essexite or its equivalent, according to the texture and mode of occurrence.

A purely mineralogical classification, as already pointed out by many petrologists, cannot hope to attain complete parallelism with a normative classification. The mere existence of such alferric minerals as hornblende and pyroxene assures that unfortunate fact. Nevertheless, all the co-ordinates of the C.I.P.W. Classification (with the modification suggested above) are available for a modal classification.

(*a*) The ratio of felsic to mafic minerals is an important characteristic, but certainly not sufficiently so to take first place. If the mineral composition is quantitatively stated, then the ratio is known and may be used for various purposes, such as a subsidiary means of classification, or as a test of rival theories of differentiation. The terms *leucocratic* and *melanocratic* should, in the opinion of the writer, be used without exact quantitative significance, to express variations within a single body of rock, or within a series of associated rocks, relative to the average, or (assumed) parent rock type. For quantitative divisions the modal terms *felsic* and *mafic* are available, and with the C.I.P.W. limits and terminology rocks may be described as perfelsic, M_0–$M_{12\cdot5}$ (using M for mafic constituents with percentage suffixes); dofelsic, $M_{12\cdot5}$–$M_{37\cdot5}$; mafelsic, $M_{37\cdot5}$–$M_{62\cdot5}$; domafic, $M_{62\cdot5}$–$M_{87\cdot5}$; and permafic $M_{87\cdot5}$–M_{100}. (See also Shand, 1916, pp. 400–4.) Tyrrell's suggestion to group the first two of these

[1] The occasional presence in oversaturated rocks of fayalite with tridymite, or other forms of silica, need not invalidate this statement, provided that the term "olivine-bearing rocks" is understood to imply magnesian olivine and to exclude fayalite. The presence of the latter in a rock as a rare accessory does not affect petrographical nomenclature, and as Shand has pointed out, it exists in the company of free silica because an orthorhombic pyroxene of the composition $Fe\,Si\,O_3$ is apparently incapable of a separate existence. (Shand, 1914, pp. 491–2; see also Washington, *Journ. Geol.*, xxii, p. 16, 1914.)

III.

UNDERSATURATED ROCKS: CHARACTERIZED BY OLIVINE.

	Or_0 Soda $Or_{12.5}$	Rocks. $Or_{37.5}$	Soda-potash Rocks. $Or_{62.5}$	Potash $Or_{87.5}$	Rocks. Or_{100}
Albite.		Olivine alkali-syenites. Laurvikite (in part). Rhomb-porphyry (in part). Olivine-alkali-trachytes. Skomerite. Olivine kenyte.			
An_{15}					
Oligoclase-andesine.	Olivine diorite. Olivine andesite. Mugearite.		Olivine monzonite[1] (in part?). Olivine trachy-andesite. Olivine latite.		
An_{50}					
Labradorite-anorthite.	Olivine gabbro. Olivine anorthosite. Olivine norite. Olivine hyperite. Olivine dolerite. Olivine diabase. Olivine basalt.		Olivine monzonite. Kentallenite. Absarokite. Olivine trachy-dolerite. Ciminite.		
An_{100}					
Felspar absent or accessory.	Picrite. Olivine pyroxenite. Limburgite. Picrite-basalt.				
Felspar absent.	Peridotite. Wehrlite. Lherzolite. Cortlandite. Dunite.		Mica-peridotite. Kimberlite.		

[1] See footnote on p. 121.

divisions together as "leucocratic" gives too broad a meaning to the term, for as a rule only perfelsic rocks could accurately—with due respect to their prevalent colour—be described as leucocratic.

(*b*) A much more valuable basis for a primary subdivision of rocks is that recently proposed by Shand (1913, p. 313). In part it corresponds to the orders of the C.I.P.W. Classification and to the vertical divisions of the mineral classification tabulated by Iddings (vol. i, pp. 348–9), but it goes a step further since it contrasts quartz-bearing rocks not only with felspathoid-bearing rocks, but also with rocks characterized by the presence of olivine and of other unsaturated minerals. Shand's contribution to "the framework of a classification" (1915, p. 340), is as follows:—

I. Oversaturated Rocks, which contain free silica of magmatic origin.
II. Saturated Rocks, which contain only saturated minerals (i.e. saturated with regard to silica).
III. Undersaturated Rocks, which contain unsaturated minerals:
  (*a*) Dyad metals undersaturated, e.g. *olivine*-bearing rocks.
  (*b*) Monad metals undersaturated, e.g. *felspathoid*-bearing rocks.
  (*c*) Monad and dyad metals undersaturated, e.g. *felspathoid and olivine* bearing rocks.

In the classification advocated in this paper Shand's five groups are adopted as those of first importance. The principle of saturation is one far superior in its significance to the old conception of igneous rocks as acid, intermediate, basic, and ultrabasic. If the term *acid* means anything at all, as applied to rocks, it suggests the presence of free silica, and quartz-diorites and gabbros should, according to this implication, be classed as "acid rocks". On the other hand, if the term *basic* were logically applied, it would include nepheline-syenites as well as olivine-gabbros.

(*c*) The value of salic or felsic minerals in classification is indicated by the fact that in the norm of Clarke's average igneous rock, the salic minerals amount to 79 per cent of the total (Cross, 1912, p. 759; Tyrrell, p. 69). Moreover, the felspars alone constitute 67 per cent of the total norm. Clarke has also given a modal average of igneous rocks, and according to his figures the felspars constitute practically 60 per cent. The felspars are therefore well adapted for a further division of rocks within each of the five groups separated according to the saturation principle. Since there are three felspar molecules, orthoclase, albite, and anorthite, with albite as a common associate of each of the others, the ratios of albite to anorthite and of orthoclase to albite afford excellent co-ordinates for a cross classification. The writer considers that it is of doubtful value to use the ratio of orthoclase plus albite to anorthite, as is suggested by Tyrrell (p. 79); or that of alkali felspars to soda-lime felspars, as is done by Iddings (*Igneous Rocks*, vol. ii). In the former ratio the kind of soda-lime felspar does not appear in the classification (as in the case of the present method of calculating the rang), and in the latter ratio the terms compared are not independent.

It is proposed in this paper to divide felspathic igneous rocks according to the kind of soda-lime felspar present—the kind being conveniently expressed by the percentage of anorthite. At least

IV.

UNDERSATURATED ROCKS: CHARACTERIZED BY FELSPATHOIDS.

	Or_{0} SODA $Or_{12\cdot5}$ ROCKS. $Or_{37\cdot5}$	SODA-POTASH ROCKS. $Or_{62\cdot5}$	POTASH $Or_{87\cdot5}$ ROCKS. Or_{100}
ALBITE.	Mariupolite. NEPHELINE SYENITE. Laurdalite. Foyaite, Ditroite. Litchfieldite. Covite. Eudialite syenite. Shonkinite. NEPHELINE-SYENITE PORPHYRY. Tinguaite porphyry. Tinguaite. NEPHELINE PHONOLITE.		Borolanite. Leucite syenite. Leucite shonkinite. LEUCITE PHONOLITE.
An_{15} OLIGOCLASE-ANDESINE.	ESSEXITE (in part).	Shonkinite (in part). Vicoite. Kulaite (in part).	Marosite.
An_{50} LABRADORITE-ANORTHITE.	THERALITE. Essexite (in part). TESCHENITE. Analcime dolerite. Camptonite (in part). NEPHELINE TEPHRITE. Analcime tephrite.	Nepheline monzonite. LEUCITE TEPHRITE. Kulaite (in part).	
An_{100} Felspar absent, or accessory.	IJOLITE. Jacupirangite. Bekinkinite. MONCHIQUITE (olivine free). Fourchite. Nepheline monchiquite NEPHELINITE.	LEUCITE MONCHIQUITE (olivine free). Ouachitite. LEUCITITE.	

three divisions are necessary, those corresponding to albite (up to An_{15}), to oligoclase and andesine (from An_{15} to An_{50}), and to labradorite to anorthite (from An_{50} to An_{100}). Symmetry seems to demand an anorthite division, and in some cases it would be useful to distinguish oligoclase rocks. Probably the five rang divisions of the soda-lime felspars would give somewhat better results, the present objection to using them being merely the lack of an appropriate nomenclature. In particular, the boundary between andesine and labradorite at An_{47} is preferable to that at An_{50}. However, these are extensions of the method which will fall naturally into place as more rocks are quantitatively examined and described.

Secondly, it is proposed to divide the rocks further according to the ratio of orthoclase to albite, or, stating it more generally, according to the molecular ratio of potash to soda. The ratio is conveniently expressed by the percentage of orthoclase in total orthoclase plus albite. In order to give the felspathoid minerals and the micas due weight in the classification, these may also be expressed in terms of the amounts of orthoclase and albite to which they are approximately equivalent. The chief factors required for this conversion are given approximately in the following table:—

ORTHOCLASE	=1·0	ALBITE	=1·0
Anorthoclase	=0·4	Anorthoclase	=0·6
Leucite	=1·4	Analcime	=1·3
Muscovite	=0·7	Nepheline	=1·6
Biotite	=0·6		

Some petrologists may object to the inclusion of biotite as a mineral comparable to orthoclase, but since it may be regarded as containing a leucite-like molecule, it seems desirable to take it into consideration. The writer is aware that at this stage the classification ceases to be purely mineralogical, but it is difficult to avoid some such grouping of minerals if the classification is to be one that can readily be tabulated and memorized. To employ every important mineral as a classificatory co-ordinate would demand more dimensions than can be printed or mentally visualized. The point raised touches the question of the objects of the classification, and these may be stated as follows:—

(*a*) To attain parallelism with a chemical classification as far as possible.

(*b*) To form compartments which shall largely define and limit the types of rocks falling within them.

(*c*) To express the relations of rocks to one another; linear in a chemical and mineralogical sense, and genetic as far as this can be done by a division of space into compartments.

(*d*) To enable students of the subject easily to memorize the ever increasing list of rock names.

(*e*) To indicate to petrologists where new names are necessary, and where they may, with advantage, be avoided.

Returning from this digression to a consideration of the actual subdivisions adopted on a potash to soda basis, we may consider those that have already been used. In the C.I.P.W. Classification the five sub-rangs would give limiting positions at $Or_{12\cdot5}$–$Or_{37\cdot5}$–$Or_{62\cdot5}$–

V.

UNDERSATURATED ROCKS: CHARACTERIZED BY FELSPATHOIDS AND OLIVINE.

	Or_0 SODA $Or_{12\cdot5}$ ROCKS. $Or_{37\cdot5}$	SODA-POTASH ROCKS. $Or_{62\cdot5}$	POTASH $Or_{87\cdot5}$ ROCKS. Or_{100}
ALBITE.			
An_{15} OLIGOCLASE-ANDESINE.	OLIVINE ESSEXITE (in part).	Olivine shonkinite.	
An_{50} LABRADORITE-ANORTHITE.	OLIVINE THERALITE. Olivine essexite (in part). OLIVINE TESCHENITE. Olivine camptonite (in part). NEPHELINE BASANITE.	SOMMAÏTE. LEUCITE BASANITE. Olivine kulaite.	
An_{100} Felspar absent or accessory.	Olivine jacupirangite. Olivine bekinkinite. OLIVINE MONCHIQUITE. Alnoïte. NEPELINE BASALT. Nepheline melilite basalt. Melilite basalt.	LEUCITE OLIVINE MONCHIQUITE. Missourite. LEUCITE BASALT.	

$Or_{87·5}$. Some authors have used 1/3–2/3 (Or_{33}–Or_{67}) as the limiting ratios of orthoclase to total felspar in certain groups of rocks such as monzonite (Hatch, 1916, vol. i, p. 192). This procedure, however, compares orthoclase to soda-lime felspar, and as the composition of the latter varies according to its occurrence in (say) granites or gabbros, adamellites or labradorite-monzonites, it follows that the same factors are not used throughout. Iddings in his modal classification (vol. ii) adopts 3/8–5/8 as limiting ratios, with a still greater possibility of variation in the factors, since for orthoclase he substitutes alkali felspar.

Until we know whether there be a natural grouping of rock types about certain points (and relative abundance of the types concerned must, of course, be the chief test applied), the precise value of the limiting ratios adopted does not seriously matter. Those here employed are the ratios of the C.I.P.W. Classification, using in general only three of the five divisions. The separation of granodiorite from quartz-diorite and adamellite demands a fourth subdivision. According to the definition of Lindgren, the orthoclase limits for granodiorite are about $Or_{10}-Or_{33}$, consequently the C.I.P.W. limits $Or_{12·5}-Or_{37·5}$ will serve equally well. In the other direction, a fifth subdivision is necessary to accommodate the labradorite-monzonites which, starting at $Or_{37·5}$, may be allowed to pass over the $Or_{62·5}$ dividing-line as far as the $Or_{87·5}$ limit. These limits are broader than are actually required, but as they do no violence to the definition of a gabbro, there can be no objection to their adoption. The writer does not wish to insist on rigidly fixed lines of division, for it is his opinion that a really valuable quantitative classification can only emerge when thousands of modes have been measured and statistically examined. The mode is the only "symbol" that can at present usefully be given to a rock. Nevertheless, for a tabular statement to be possible at all, lines must be drawn somewhere, and those adopted seem to enclose all accepted rock names without changing their current significance.

There remain to be considered rocks without actual felspar. Logically, the five divisions here made on successive pages should be repeated for rocks free from felspar, the divisions giving in respective order: Quartz rocks, Pyroxenites and Hornblendites, Peridotites, Felspathoid rocks, and Olivine-felspathoid rocks. It is much more convenient, however, to treat each group as a limiting case of the felspar group to which it most clearly belongs. This is done in the tabulation by placing some of the rocks in question below the corresponding felspathic rocks.

In each division of the tabular scheme, the coarse-grained rocks (generally those of *major intrusions*, to use Dr. Evans' convenient term for 'plutonic' masses) are used as types, and allied porphyritic, fine-grained, or aphanitic varieties (belonging generally to minor intrusions and lava-flows) are grouped with them.

The classification is printed in three dimensions, in sheets superimposed one on another as required. Of these dimensions, the first is based on degree of silica-saturation, and since it involves lines of variation from saturated types in the directions respectively of quartz, felspathoid, and olivine, it really constitutes a classification on three co-ordinates. To make quantitative divisions the ratios of quartz to felspar, felspathoid to felspar, and of olivine to felspar or mafic minerals, could be employed. In particular it should be pointed out that in the table of oversaturated rocks, quartz-syenites have been squeezed out by the granites, and only consideration for space has deterred the writer from inserting a second sheet to include rocks with small amounts of quartz (on which such rocks as quartz-gabbro would then have properly appeared). The fourth and fifth co-ordinates, printed as second and third dimensions, are quantitative, and depend respectively on the ratios of albite to anorthite (expressed by percentages of anorthite), and of orthoclase (including other potash minerals suitably weighted) to albite (including other felsic soda minerals suitably weighted). A remaining feature, unexpressed in the tables, is the ratio of felsic to mafic minerals. The classification and nomenclature arising from this ratio have already been described; and in practice the ratio constitutes a sixth co-ordinate that may often be of great service as a further means of subdivision. The seventh and last co-ordinate is textural.

Vogt (see Harker, p. 373) has pointed out that in the peridotites the atomic ratio of magnesium to iron gradually increases as the amount of alumina decreases. Dr. Prior has also used the ratio of MgO/FeO with excellent results in a recent and illuminating classification of meteorites (*Min. Mag.*, p. 42, 1916). It may be worthy of notice that in the mineralogical classification of this paper, the same ratio increases from the north-east corner of each sheet to the south-west corner, for rocks having a normal "colour ratio" or felsic/mafic ratio. Indeed, for all such rocks (as far as can be tested by "average" analyses) the chemical variation in any direction is approximately regular.

Glassy rocks are necessarily incapable of treatment, as indeed they must be by any system of classification by minerals. Similarly, most altered rocks, whether they be altered by pneumatolytic or other processes arising from the consolidation of their parent magma, or by weathering processes, must also be excluded. A classification appropriate to express their characters would be based on the processes by which they have been altered, and the mineral and structural changes whereby their new features have been developed.

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REVIEWS.

I.—NEW LIGHT ON THE CALEDONIAN THRUST MOVEMENTS IN NORWAY.

VOL. IV, part i, of the *Norsk Geologisk Tidsskrift*, just published, contains a summary of an exceptionally interesting paper on the tectonics and formation of the Norwegian mountains, read before the Geological Society of Norway by Professor V. M. Goldschmidt, of Christiania University.[1] As the Norwegian and Scottish Highland rocks are of similar age and nature and exhibit the same type of tectonic structure, the discoveries in one region cannot fail to be of interest to the workers in the other: the chief points of the paper are here noticed without any attempt to offer criticism. The main conclusions advanced are of a novel character and have more than a local significance, for the author uses them to elucidate the problems offered by the rocks and structures of other great mountain ranges of the world.

The paper deals with the central Norwegian mountain region in which great masses of eruptive gabbro and granite have been thrust over Ordovician phyllites. A series of arkoses, conglomerates, and schists, known as the "Høifjeldskvarts" (high-mountain quartz) is usually present overlying the phyllites, and an attempt is made to elucidate the hitherto problematical origin and age of the series, to show its relationship to the high mountain eruptives which frequently overlie it, and to demonstrate the conditions under which the Caledonian mountain-building thrust movements obtained. The great difficulty experienced in unravelling the nature and origin of the "Høifjeldskvarts" results from the extreme metamorphism to which a great part of it has been subjected. Thus, if it were possible to classify its green schists and determine their origin, much light would be thrown on many problems, but as yet there is no means of doing this, for a tuff, an agglomerate, a conglomerate, an effusive or intrusive mass may all on alteration give the same kind of amphibolite schist. A district was therefore chosen for investigation in which the regional metamorphism is a minimum, and there are fewest hindrances in the way of an indisputable identification of the rocks. Such a district was found in Central Norway to the east and west of Valdres, north-west from Christiania.

In the first tract discussed, that between Valdres and Gudbrandsdal, the sedimentary origin of the "Høifjeldskvarts" can be established beyond doubt. The series here occupies an extensive area, and

[1] V. M. Goldschmidt, "Om høifjeldskvartsen I og II": *Norsk Geologisk Tidsskrift*, Bd. iv, Hefte i, pp. 44–6, 49–53, Kristiania, 1916.

interbedded in it are conglomerates essentially composed of gabbroid stones. The problem is to determine the relationship of these conglomerates to some adjacent gabbro mountain masses which owe their present position to thrusting. In an early paper Bjørlykke held that the conglomerate was derived from the gabbro, and was thus the younger formation. In a later communication, however, the contrary opinion is expressed that the gabbro is younger than the "Høifjeldskvarts", and was intruded between it and the underlying phyllites. Professor Goldschmidt has made a thorough microscopic investigation of these rocks. The massive gabbro is a very characteristic rock composed of very fresh augite, less fresh biotite, and a wholly decomposed plagioclase; hornblende varieties also occur. The pebbles of the conglomerate exhibit all the varieties of the massive mountain gabbro, from which they are clearly derived. Thus the "Høifjeldskvarts" cannot be older than the mountain-building movements, since these conglomerates were laid down after the gabbro masses had reached their present position. Again, the conglomerate can be followed to places where it is overlaid by the gabbro and has been strongly pressed, often almost out of recognition. Thus the "Høifjeldskvarts" cannot be younger than the thrusting movements, seeing it has been metamorphosed during, and as a result of, their evolution. It is not pre-Caledonian; it is not post-Caledonian; it is Caledonian —a conclusion of great significance, for it shows that the thrusting took place at the earth's surface, a conglomerate being laid down during the process. The gabbro was eroded in front, whilst it was being pushed forward from behind.

The second tract examined lies between Valdres and Hemsedal. Here we have a similar type of structure, only the Ordovician phyllites are overlaid by thrust masses of granite instead of gabbro. In the south of the district the conglomerate beds are seen overlying the granite as a normal basal deposit, with no evidences of pressure action. In the north, on the other hand, the conglomerate has been overridden by the granite, and its pebbles have been pressed and drawn out by the movement. Here also the derivation of much of the conglomerate from the granite which now overlies it is established.

Thus the investigations in both of these districts lead to the conclusion that the sedimentation of the "Høifjeldskvarts" took place whilst the great eruptive masses were being driven forward, and with deposition of material from the erosion of the selfsame masses. By the continuance of the thrusting movements the sediments were covered and metamorphosed. On this interpretation, and in opposition to the orthodox view that the great thrust movements have obtained at a considerable depth, it must be admitted that great mass-thrusting can take place "in daylight" at the surface, so that a mass can be driven forward and be subject to erosion at one and the same time, in such a way as to ride over its own debris. After mentioning the great amount of work which yet remains to be done before all the problems of the "Høifjeldskvarts" can be solved, and the flood of light which a full understanding of this series must throw not only on the formation of the Norwegian mountains but on the general principles of tectonic geology, it is confidently affirmed that "the old dogma limiting the great thrust movements to a great depth stands no more".

Professor Goldschmidt parallels the Flysch with the "Høifjeldskvarts" formation. Just as the "Høifjeldskvarts" is Caledonian, so the Flysch is Alpine in age, being formed contemporaneously with the mountain-building movements, though the petrographical similarity between the two formations is very small, one obtaining its material from forward-thrust eruptives and the other from forward-thrust Mesozoic sediments. In the discussion following the reading of the paper Professor Brøgger expressed his approval of the original views set forth, and the further work of the Norwegian geologists in the light of the new theory will be followed with great interest.

L. Hawkes.

II.—On some Cretaceous Brachiopoda and Mollusca from Angola, Portuguese West Africa. By R. Bullen Newton. Trans. Royal Soc. Edinburgh, vol. li, pt. iii, No. 15, August, 1916.

The fossils described in this paper were collected by Professor J. W. Gregory and Mr. E. Robins from a cream-coloured limestone in the neighbourhood of Lobito Bay, north of Benguella in Angola. Most of the specimens are poorly preserved, but the author considers that there is sufficient evidence to refer the fauna to the Vraconnian stage, and this view receives support from the Cephalopods which have been examined by Mr. G. C. Crick. Twenty species are described, of which only seven are definitely identified with forms already known, and two are described as new. Twelve of the species are either identified or compared with European forms. The 'Brazilian facies' of the fauna mentioned by the author seems to depend mainly on some resemblance between *Akera Gregoryi* and *A. Browni*, since the other species common to Angola and Brazil are widely distributed forms.

The species recorded by Mr. Newton are: *Terebratula depressa*, Lam., *Exogyra* cf. *flabellata*, Goldf., *Neithea æquicostata*, Lam., *N. angoliensis*, sp. nov., *N. quadricostata*, Sow., *N. tricostata*, Coq., *Lima* cf. *iteriana*, P. & C., *Volsella* sp., *Trigonarca* cf. *ligeriensis*, d'Orb., *T.* cf. *diceras*, Seg., *Trigonia crenulata*, Lam., *Anthonya* cf. *Baudeti*, Coq., *Trachycardium* cf. *syriacum*, Conr., *Panopæa* cf. *plicata*, Sow., *Pholadomya* cf. *Vignesi*, Lart., *Toucasia* sp., *Tylostoma globosum*, Sharpe, *Hipponyx* sp., *Akera Gregoryi*, sp. nov.

III.—Illinois Fossil Invertebrates.

1. *Atactocrinus*, a new Crinoid genus from the Richmond of Illinois (pp. 239–41, pl. xv).
2. Description of a Ste. Genevieve Limestone Fauna from Monroe County, Illinois (pp. 243–65, pls. xvi–xix).

By Stuart Weller. Being Contributions from Walker Museum, vol. i, No. 10. University of Chicago, April, 1916. Price 1*s.* net.

What the Walker Museum may previously have contributed seems generally unknown in this country, but if the isolated part that has reached the review-office of the Geological Magazine be a fair sample we should be glad to see more.

1. The genus *Atactocrinus*, here carefully described, is regarded as a Dicyclic Camerate crinoid of which only the following plates are known: 5 infrabasals, 5 basals, 5 radials, 5 primibrachs, and 5 interradials, each of the last supporting 2 interbrachials. Its peculiarity is that two adjoining interradii and a third opposite to them separate the adjacent radials, whereas across the two remaining interradii the radials meet; consequently three of the basals are truncate above, while the other two are pointed. Thus the cup is bilaterally symmetrical in its irregularity.

Dr. Weller regards the genus as intermediate between the Dimerocrinidae and the Rhodocrinidae, and says that "if the two antero-laterals [basals] were pointed it could be . . . placed in the Dimerocrinidae". In that Family, however, the posterior interradial supports three plates, not two as here and as frequently in the Rhodocrinidae. The last-mentioned Family comprises a genus in which the lower part of the cup is composed of the same number of plates having the same general arrangement, namely *Lyriocrinus*. In that genus, as Wachsmuth & Springer have pointed out, the basals may be all truncate above or "quite frequently one or more of them hexagonal, and angular at the top". Why then is Dr. Weller's specimen not a *Lyriocrinus* with two basals in the latter condition? In the portion preserved the only points of difference from Wachsmuth and Springer's diagnosis are the slightly greater prominence of the infrabasals, correlated with the less depression of the lower part of the cup. This is consistent with its lower horizon, at the top of the Ordovician, previously known species being Middle Silurian. The ornament differs from that of the other American species, but is of the same general nature as that seen in some examples from the Wenlock Limestone (Brit. Mus., E 14697, E 15617). The assigned columnals are higher and more bead-like than usual in the genus, but in the Wenlock specimen (Brit. Mus. E 7095) the most distal of the columnals preserved approach this shape.

2. The Sainte Genevieve Limestone, of Middle Carboniferous age, lies between the Kaskaskia and the St. Louis Limestone, with which latter it was till recently confused. To help towards the distinguishing of its fauna, the second paper describes a collection from a single locality and bed. It makes known 26 new species of Lamellibranchs and Gastropods. All species, old as well as new, are illustrated by half-tone reproductions of photographs, enlarged two or four diameters. The results are no more beautiful than are usual with this process; it is to be hoped they may prove more useful.

It is not stated that the specimens described in these two papers are preserved in the Walker Museum of Chicago University.

F. A. Bather.

IV.—The Structure and History of Plav: the Floating Fen of the Delta of the Danube. By Marietta Pallis. Journal of the Linnæan Society, vol. xliii, pp. 233–90, 1916.

PLAV is the name given to the floating reed fen which is found in the Balta or marsh district in the delta of the Danube. It is chiefly composed of the interlacing vertical rhizomes of the giant reed, *Phragmites communis*, Trin., *β. flavescens*, Gren & Godr. These, with the soil which they retain by the aid of their roots, form a subaqueous mass about 6 feet in thickness. This can be divided into three layers: the uppermost, about 6 inches thick, with a very highly organic black soil in which are rooted various water plants; the middle, about 18 inches thick, with a lighter soil containing 40 per cent of organic matter; and the lowest, about 4 feet thick, with a soil having an organic content of only 17 per cent. From these rhizomes grow reed shoots as high as 17 feet, which form the aerial portion of the Plav.

The formation of Plav takes the following course: first round the sandbanks an "open reed swamp" forms (i.e. a swamp in which the reeds are fairly widely separated from one another). This in course of time by the spreading of the reeds becomes thicker, forming a "closed reed swamp". This swamp then begins to lose its hold on the ooze in which it is rooted by the death of some of the lower rhizomes; if then the water is not shallow enough for the mass of rhizomes to fill it entirely to the surface, the hydrostatic pressure on the upper layers will cause the mass to rise, and it will become floating reed swamp or Plav. The three necessary conditions then for the formation of Plav are: that the water should be sufficiently deep; that the floods do not bring down much silt which would lessen the depth of the water so that the lower rhizomes could become re-rooted; and that the basal decomposition should set in in the swamp stage and not in the fen stage, as happens in Norfolk, where the reeds fill up the whole water space before basal decomposition sets in.

Some Plavs are miles long, and are attached at one side or end; others, however, are quite small and form floating islands. These latter may be broken pieces of the larger Plavs, but more probably originated on a small bank so that they became free floating when detached at the base. To what extent Plav may be regarded as another substance for coal is not very clear. The large amount of inorganic soil it contains would indicate a higher ash content than is usual in most coals. If, however, the delta of the Danube were invaded at some early date by the sea something very much resembling coal would, no doubt, be found there.

W. H. W.

V.—Geological Notes, Northern Territory, Australia. By E. J. Dunn. Proc. Roy. Soc. Victoria, vol. xxviii (n.s.), pt. i, pp. 112–14.

In this publication Mr. E. J. Dunn describes a portion of the core of a borehole, where the appearance of highly contorted strata has been produced in rocks of Carboniferous age by the boring of worms. The worms made tortuous holes in black mud at a time when white sand was being deposited. This washed into the holes and filled them up, giving the appearance of a high degree of contortion.

He also describes how the formation of rounded pebbles may take place without the wearing action of water. At the mouth of the

Victoria River large numbers of fragments of quartzite are found just above high-water mark. These in time are changed from angular fragments to rounded pebbles with a rough surface. This seems to be caused by the continual wetting of the stones with sea-water, followed by crystallization of the contained salts by the heat of the tropical sun. It is not certain whether the action is a chemical or a physical one, or whether it is a mixture of the two; but the result seems to be that the secondary quartz cement is removed, leaving the primary quartz grains standing up to form a roughened surface.

W. H. W.

VI.—Brief Notices.

1.—Detrital Andalusite in Cretaceous and Eocene Sands. By G. M. Davies, B.Sc., F.G.S. Min. Mag., vol. xvii, No. 81, pp. 218–220, 1915.

IN this short paper Mr. G. M. Davies records the occurrence of unaltered pleochroic andalusite in many Eocene sands of the London district, in the Lower Greensand of Reigate, Limpsfield, and Folkestone, and even in the Wealden beds of Spotover Hill near Oxford. He mentions also that the mineral has been observed in the St. Bees Sandstone, of Triassic age. These observations will serve to reverse the opinion formerly held that, owing to its instability, andalusite would not be found in strata older than the Pliocene.

W. H. W.

2.—Fauna of the Fernando of Los Angeles. By Clarence L. Moody. University of California Publications, Bulletin of the Department of Geology, vol. x, No. 4, pp. 39–62, pls. i–ii, 1916.

THE fauna referred to in this memoir consists mainly of mollusca, of which there are stated to be 147 species, only about ten species being represented of other groups such as the Echinoidea, Brachiopoda, Bryozoa, etc. The following new species are described and figured: **Gastropoda**, *Siphonalia gilberti*, *Chrysodomus dirus meridiei*, var. nov., *Trophon raymondi*, *Columbella* (*Astyris*) *constantia*, *Turris* (*Drillia*) *modestus*, *Borsonia inculta*, *Mangilia muricidea*, *Cancellaria quadrata*; **Pelecypoda**, *Pecten* (*Propeamusium*) *levis*, *Macrocallista densa*, *Corbula tenuis*. The author regards the fauna as presenting a boreal aspect, and nearly similar to that characterizing the San Pedro Pliocene beds of California, which has been described by Dr. Ralph Arnold, and which belongs to the lower horizons of the San Diego formation.

R. B. N.

3.—Some American Fossil Insects. By T. D. A. Cockerell. Proc. United States Nat. Mus., vol. li, pp. 89–106, pl. ii, No. 2146, 1916.

THE specimens described in this paper range in time from the Coal-measures to the Miocene, while the author's studies of their structures have enabled him to recognize certain new genera as well as new species which may be listed as follows—**Diptera**: *Plecia woodruffi* from the Green River Eocene beds of Utah, *Psilocephala* *scudderi*, *Oxycera rohweri*, *Empis perdita*, *Protolomatia recurrens*, *Protepacmus* (nov. gen.) *setosus*, *Pachysomites* (nov. gen.) *inermis*, *Tabanus merychippi*, *Chilosia sepultula*, *Sciara florissantensis*, *Cordylura exhumata*, *Chironomus scudderiellus*, from the Miocene Shales of Florissant. **Lepidoptera**: *Tortrix* (?) *destructus*, from the Florissant Miocene. **Trichoptera**: *Dolophilus* (?) *præmissus*, Upper Cretaceous (Emscherian) of Tennessee. **Protorthoptera**: *Danielsiella* (nov. gen.) *priscula*, Carboniferous of Illinois. **Odonata**: *Lithragion* (?) *optimum*, Miocene of Florissant. **Hymenoptera**: *Aulacites* (nov. gen.) *secundus*, *Eriocampoides micrarche*, Miocene of Florissant. **Coleoptera**: *Saperda lesquereuxi*, Miocene of Florissant, *Calandrites hindsi*, *Ophryastites hendersoni*, from the Eocene of North Park, Colorado.

4.—Alexandrian Rocks of the North-Eastern Illinois and Eastern Wisconsin. By T. E. Savage. Bulletin of the Geological Society of America, vol. xxvii, pp. 305–24, pls. xv–xvii, 1916.

THE author's investigations on this subject lead him to recognize that a correlation exists between the Mayville Beds of Wisconsin and the Alexandrian rocks of North-Eastern Illinois, as also between the Alexandrian rocks of the Mississippi Valley and the early Silurian strata of Anticosti. The fossils figured and described from the Alexandrian rocks belong to the Brachiopoda; there is besides a form of *Eurypterus* (*E. pumilus*, n.sp.). Some new species or varieties among the Brachiopods are referred to the genera *Schuchertella*, *Clorinda*, *Stricklandinia*, *Platymerella*, and *Virgiana*.

5.—The Glossopteris Beds of Northern Queensland.

The Glossopteris Beds of Betts's Creek, Northern Queensland. By J. H. Reid, A.S.T.C., Fifth Government Geologist, Geological Survey of Queensland. Publication No. 254. pp. 21, with two plates (maps) and four text-figures (sections and map). With an Introductory Note by B. Dunstan, Chief Government Geologist, 1916.

THIS is an important contribution to the geology of Queensland, the beds in question at Betts's Creek having long been recognized as containing *Glossopteris* remains, although assigned by W. H. Rands to a Cretaceous age and claimed as forming part of the Desert Sandstone series. The author regards the deposits as of Permo-Carboniferous or probably of Upper Coal-measure age, mentioning that they are overlain by "Desert Sandstone" and divided by a slight unconformity. A list of the flora referred to includes *Glossopteris browniana* (Brongniart), *Vertebraria*, *Phyllotheca*, etc.

6.—New Brachiopods of the genus *Spirifer* from the Silurian of Maine. By Henry Shaler Williams. Proc. United States National Museum, vol. li, pp. 73–80, pl. i, No. 2144, 1916.

THE species described in this pamphlet are said to exhibit a closer relationship to the Wenlock–Ludlow formations of Great Britain than to the Niagara of the interior of the American Continent. They were obtained from the Edmunds formation of Washington County, Maine, and include: *Spirifer* (? *Delthyris*) *trescotti*, *S. cobscooki*, *S. edmundsi*, *S.* (cf. *Cyrtina*) *lubecensis.*

REPORTS AND PROCEEDINGS.

I.—Liverpool Geological Society.

January 9, 1917.—J. H. Milton, F.G.S., F.L.S., President, in the Chair.

The following paper was read:—

"The Millstone Grit of Yorkshire." By Albert Gilligan, B.Sc., F.G.S.

The petrography of this great series of rocks has been almost entirely neglected since the classic work of Dr. Sorby, carried out in the middle of last century. From the evidence of the pebbles found in the grit beds, Sorby concluded that the material making up the series had been derived from a landmass having the same lithological characters as the Scandinavian Peninsula, which probably formed an extension of that peninsula to the south-west.

For many years Mr. Gilligan has been engaged in examining not only the pebbles but also the general material making up the series, and has further made a study of the heavy minerals of a large number of the beds. Among the larger pebbles have been found quartz and felspar porphyries, granites of various types, gneisses, schists, sandstones, and mudstones. The source of some of these can be traced to Scotland, while one of them so much resembles the well-known rhomb-porphyry of the Christiania region as to suggest that it represents one of the facies of that rock. Quartz pebbles are abundant in all the coarser beds, and these invariably show the effects of pressure, many presenting a mylonized structure. The pink felspar pebbles are always exceedingly fresh, and in nearly all cases are found to be microcline or microcline-microperthite. Pieces of pegmatite, the constituents being quartz and microcline, are common in all the beds, but most abundant in the Kinder Scout and Rough Rock. A few small pebbles of great rarity show oolitic structure, while others contain traces of organisms such as sponge spicules, etc. Chert pebbles differing from those specimens which have been examined from the underlying Carboniferous beds have been obtained from the coarse beds.

The heavy minerals are very irregularly distributed, some layers being extremely rich, while an adjacent bed will yield but a small number. They include the following: ilmenite, magnetite, garnet, zircon, rutile, tourmaline (blue and brown), anatase, and monazite. This last mineral is of great interest, and was first found in the garnetiferous layers of the Rough Rock, and has since been discovered in the basement grit of Pen-y-gent and the Middle Grits of the Aire Valley.

The Millstone Grit shows such striking resemblances to the Torridon Sandstone that Mr. Gilligan is disposed to think that they were in great part derived from a common source.

The paper was illustrated by specimens and by a beautiful series of lantern slides of scenery and photomicrographs.

II.—Geological Society of London.

1. *January* 24, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

Dr. Aubrey Strahan, F.R.S., Director of H.M. Geological Survey, addressing the President and Fellows, said that in 1914 a proposal was made to subscribe for a bust of Sir Archibald Geikie which would be presented to the Board of Education for preservation in the Museum of Practical Geology. Notwithstanding that war broke out shortly after the scheme was launched, the proposal was warmly supported by geologists at home and abroad, and among others by Fellows of the Society. A marble bust, executed by Professor E. Lantéri, of the Royal College of Art, was presented to the Board on March 14, 1916, and placed in the Museum. At the same time a replica was presented to Sir Archibald, who has since made it a gift to the University of Edinburgh, where he was the first Murchison Professor. The past and present staff of the Geological Survey and Museum, thinking that a copy of the original model of the bust would be a suitable gift to the Geological Society of London, in whose affairs Sir Archibald had taken so prominent a part, had caused a cast to be made, and Dr. Strahan, on their behalf, offered it for the acceptance of the Society.

The President, referring to Sir Archibald Geikie's long and intimate connexion with the Society, gratefully accepted the gift on behalf of the Fellows.

Mr. Scoresby Routledge, M.A., gave an account of Easter Island. He said that the expedition that he had had the honour to command was organized with the object of carrying out a long-standing wish of various bodies interested in anthropology. This wish was that Easter Island, and other islands most near to it, though far distant from it, should be thoroughly examined, and that all information and material thereon found should be carefully considered on the spot, or, if possible, be brought back for comparative study.

This programme necessitated a vessel being specially designed, built, and equipped for the purpose. A schooner with auxiliary motor power, the *Mana*, of 90 tons gross register, 78 feet on the water-line, 20 feet beam, and drawing 10·5 feet aft, was accordingly completed by the end of 1912, and she sailed from Southampton in February, 1913, with a company of twelve all told, of whom four formed the scientific staff. After the longest voyage ever made by a yacht under canvas, she sailed into Southampton again in June, 1916, without having experienced accident to man or material.

The course taken was through the Magellan Straits, and thence through the labyrinth of Andean waterways that stretch north therefrom, and are known as the Patagonian Channels.

On reaching Juan Fernandez Island, the *Mana* had to put back to Valparaiso because the geologist of the expedition, the late Mr. F. L. Corry, had contracted typhoid fever on the Chilean coast. Mr. Corry never recovered sufficiently to allow him to rejoin the expedition. Hence no formal geological report on the island could be submitted to the meeting. It was thought best, therefore, to endeavour to convey the conditions existent on Easter Island by means of a series of panoramic and other photographs, specially taken to illustrate geological features. As these very largely consist of coast-sections, the opportunity was taken to show, and explain, other pictures that were closely associated with them. Such were the ruins of the village called Orongo, consisting of peculiar canoe-shaped houses built of imbricated slabs of shale, with the roof convex, both longitudinally and transversely, on its exterior aspect, and covered with earth. They are romantically situated on the rim of the volcano of Rano Kao, with an almost sheer drop of 900 feet into the sea, or of 600 feet into the crater-lake. At Orongo, too, are found certain large rocks, carved with the symbol of a bird-headed man, holding in its hand an egg. A cult, based on annually obtaining the first-laid egg of a certain migratory sea-bird, was thus gradually brought to light, and appears to be a unique form. A brief outline only could be given of some of the knowledge obtained concerning the peculiar routine associated with seeking, and taking, the sacred egg, and of the part which it occupied in the former religious life of the island.

Proceeding along the coast, typical examples of the great terraces, and their giant stone figures, were shown, and their leading characteristics discussed. A submarine freshwater spring, near the great image-terrace of Tongariki, and opposite certain typical lava-formed caves, gave occasion to the lecturer to explain how had arisen the longstanding and worldwide spread report that man and beast on Easter Island habitually drink sea-water in the place of fresh.

The old volcano of Rano Raraku, the centre of the former religious life of the island, was then described. A series of panoramic pictures, preceded by an accurate survey made by Lieut. R. D. Ritchie, R.N., the cartographer of the expedition, showed a crater-lake surrounded by a rim of tuff which rises to a height of 540 feet above the surrounding plain. The plain is undulating in surface, formed superficially of hard, dense, but nevertheless vesicular lava, and it rests on compact non-columnar basalt. One section of this crater wall, some 600 yards long, on both its interior and exterior aspects, was seen to be quarried right up to the highest point. On the mountain face, both inside and out, large numbers of statues, in every state of completion, were to be seen. The largest of these measured 68 feet in length. Some of those excavated by the expedition exhibited fine details, such as the finger-nails, in perfect condition.

In conclusion, Easter Island might be described as a plateau of basalt raised from 50 to 100 feet above the sea. Superimposed on this were numerous cones ranging up to nearly 2,000 feet. The plateau was covered but sparsely with soil, and could only be crossed with difficulty in any direct line. The cones, on the other hand, were generally smooth of surface, with a good depth of soil. Nevertheless the island is practically without trees, bushes, or shrubs.

A short discussion followed, to which the Lecturer replied; and the cordial thanks of the meeting were accorded to Mr. Routledge for his lecture.

A large series of lantern-slides and specimens of the rock of which the stone images of Easter Island were made were exhibited by Mr. Scoresby Routledge, M.A.

Mr. J. B. Scrivenor, M.A., F.G.S., Government Geologist to the Federated Malay States, exhibited a manuscript geological map of the Malay States. This map, which he presented to the Society, was prepared by himself from all sources, and represented all that was known of the geology of the region at the end of the year 1916.

Anniversary Meeting.

2. *February* 16, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following extract is taken from the Report of the Council for 1916:—

Awards and Medals.

The fourteenth Award from the Daniel Pidgeon Trust Fund was made on April 5, 1916, to John Kaye Charlesworth, M.Sc., Ph.D., who proposed to conduct researches in connexion with the Glaciation of Donegal.

The following Awards of Medals and Funds have also been made:—

The Wollaston Medal is awarded to Professor Antoine François Alfred Lacroix, in recognition of his "researches concerning the Mineral Structure of the Earth", especially in connexion with the Mineralogy and Petrology of France and her Colonies.

The Murchison Medal, together with a sum of ten guineas from the Murchison Geological Fund, is awarded to Dr. George Frederic Matthew, as an acknowledgment of his valuable work on the Stratigraphy and Palæontology of the Lower Palæozoic Rocks of North America.

The Lyell Medal, together with a sum of twenty pounds, is awarded to Dr. Wheelton Hind, as an acknowledgment of the value of his contributions to the Geology of the Carboniferous Rocks of Britain, and of his researches on the Palæozoic Lamellibranchia.

The Bigsby Medal is awarded to Mr. Robert George Carruthers, as a mark of appreciation of his work on the Carboniferous Anthozoa and of his contributions to Scottish Geology, and to stimulate him to further research.

The Balance of the Proceeds of the Wollaston Donation Fund is awarded to Dr. Percy George Hamnall Boswell, in recognition of his investigations on the Tertiary and Quaternary Deposits of East Anglia, and on the Petrology of the Sedimentary Rocks.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Dr. William Mackie, as an acknowledgment of his valuable work on the Sedimentary and Igneous Rocks of Scotland, especially in connexion with his researches on the Petrology and Palæontology of the Old Red Sandstone of Elgin.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Dr. Arthur Hubert Cox, in recognition of the value of his contributions to the Stratigraphy of the Lower Palæozoic Rocks of South and Central Wales.

A second moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Tressilian Charles Nicholas, as an acknowledgment of his work on the Stratigraphy and Palæontology of the Lower Palæozoic Rocks of North Wales.

The Balance of the Proceeds of the Barlow-Jameson Fund is awarded to Mr. Henry Dewey, in recognition of his contributions to the Geology of the South-West of England and of his researches in connexion with Quaternary Deposits.

III.—Mineralogical Society.

January 16, 1917.—W. Barlow, F.R.S., President, in the Chair.

A. Holmes and Dr. H. F. Harwood: The Basalts of Iceland, Färoe Islands, and Jan Mayen. The basalts described fall into four well-marked types based on the presence or absence of olivine and the porphyritic or non-porphyritic character of the structure. They resemble the Greenland basalts previously described by the authors, and the whole series is closely matched by the basalts of Skye and County Antrim. Chemically the most striking feature of the lavas is their high content of titanium dioxide, which in the seven analyses made varies from 2·36 to 5·68 per cent. The olivine-free rocks are remarkable for their abundance of titaniferous magnetite. In the olivine basalts this mineral is less abundant, and much of the titanium is presumably in the pyroxene, which in the olivine varieties only is of a purple-brown tint. A peculiarity of the olivine basalts is their comparative richness in alkalies, a feature that brings them into relationship with the titaniferous-olivine basalts of the Western Mediterranean described and analysed by Washington. The Arctic province, however, is distinguished by the abundance of alkali-poor basalts, which in spite of the fact that their silica percentages are low are thoroughly over-saturated rocks.

Professor H. Hilton: On the use of the Orthographic Projection in Crystallography. The method of preparing a projection and its use in the drawing of crystals were explained, and the advantages of this projection of the sphere were pointed out.

J. V. Samojloff: Palæophysiology, the Organic Origin of some Minerals occurring in Sedimentary Rocks. In connexion with the exploration of the phosphate deposits of Russia, the occurrence of barytes has been noted over a wide area in the governments of Kostroma, Kazan, and Simbirsk, and also further to the north-east in the basin of the Pechora River. The mineral occurs as nodules in the clays and marls of the Upper Jurassic, and is confined to the Oxfordian–Sequanian horizon, though extending up to the Kimmeridgian in some of the districts. Nodules of barytes have been dredged from the sea-floor off the coast of Ceylon, and granules of barium sulphate have been detected in the bodies of certain marine organisms, namely the Xenophyophora. If, therefore, during the Upper Jurassic period such organisms, capable of extracting barium salts from sea-water, were more abundant, they would account for the accumulation of barium in these strata, where the barytes occur as a primary mineral. Similarly, the mineral celestite has been found over a very wide area in Turkestan in beds of Upper Cretaceous age. The presence of strontium sulphate has been detected in the skeletons of the Acantharia, a group of the Radiolaria. It is conceivable that similar organisms were relatively more abundant during the Cretaceous period, and that their remains gave rise to the deposits of celestite. Although the iron compound hæmoglobin plays an important function in the blood of present-day animals, yet cases are known amongst the Crustacea and Mollusca in which the copper compound hæmocyanin performs the same function, and vanadium has been detected in the blood of the Ascidia. During former periods of the earth's history these, and perhaps some other, metals may have been predominant in the blood of animals then living. In this connexion the persistent occurrence in the Permian strata of copper minerals and ores associated with abundant animal remains is significant. Similarly, there may have been at different periods variations in the chemical composition of the ash of plants. The recurring presence of minerals of primary origin in certain sedimentary strata therefore suggests that there may have been varying physiological processes during past periods, and for this new branch of palæontology the name "Palæophysiology" is suggested.

E. S. Simpson: On Tapiolite in the Pilbara Gold-field, Western Australia. The mineral, which was discovered at Tabba-Tabba Creek and Greens Well, lying in a large area of granite intersected by pegmatite veins and greenstone dykes and bosses, occurs in fairly well-defined crystals, which analysis proved to contain little niobium. At the first locality the crystals displayed the forms 100, 001, 111, 101, 320, and were twinned as usual on 101 and often distorted; while at the second they displayed the forms 100, 111, 101, 320, and showed twinning about 106 and 301 as well as 101. A curve was prepared showing the specific gravity obtaining in the tetragonal isomorphous series of metatantalates and metaniobates of iron, manganese, and calcium.

IV.—Edinburgh Geological Society.

January 17, 1917.—Dr. Flett, F.R.S., President, in the Chair.

1. "Low-level Kettle-holes in and near Aberdeen." By Dr. Alexander Bremner.

A number of kettle-holes, i.e. cup-shaped hollows due to the melting out of isolated masses of ice embedded in fluvio-glacial and morainic deposits, occur below the 100 ft. contour-line in the Aberdeen district. During marine submergence such hollows could not fail to be obliterated by wave action. Hence it may be inferred that in this district (1) there was no 100 ft. submergence, or (2) the submergence was anterior to or contemporary with the last advance of the local ice.

2. "The Glacial Geology of the Stonehaven District." By Dr. Bremner.

The district dealt with extends westward from the coast between Dunnottar Castle and Portlethen village to the Dee watershed and south-westward to the Bervie Water from Drumlithie upward. A description was given of the traces left by the ice which, in a phase of the Ice Age succeeding the maximum glaciation, flowed north-east from Strathmore (Strathmore Ice), and of those left by the ice which, after the final or partial disappearance of the Strathmore Ice from the district, passed over the Dee watershed and brought with it a characteristic "granite drift" (Dee Valley Ice). Striation (E. 32° S.) due to the latter ice was recorded from Beltcraig, near Portlethen. Many peculiar valleys (glacial overflow channels) were noticed, the largest being the gorge through which the Caledonian Railway runs for fully a third of the distance between Drumlithie and Stonehaven Stations.

It was pointed out that at Stonehaven, as at Aberdeen, no beach deposits referable to the 100 ft. submergence have ever been observed, but that there is strong evidence in favour of the existence of a pre-glacial rock platform (now overlaid by glacial deposits) at a level of 75 to 100 feet above O.D.

3. "Notes on River Development in the East-Central Highlands." By Dr. Bremner.

Many instances of rearrangement of drainage in the East-Central Highlands were noted, and it was proved that in Sheets 64 and 65 there occurs no authentic case of recent (post-glacial) river capture; in particular, capture of the Slugain by the Quoich was shown to be pre-glacial. (See also *Scottish Geographical Magazine* for November, 1915.)

The complicated history of the River Muick was traced in some detail. By successive captures, its headwaters (Allt an Dubh Loch) have been diverted from their original course down Glen Mark so as to enter the Dee (1) by way of the Girnock Burn and the wind-gap west of the Coyles of Muick, (2) by way of the present lower Muick.

The dismemberment of the original Tarf (Sheet 64) by the Bruar, Tromie, and Edendon, and possibly by the Mhaire, was also discussed.

CORRESPONDENCE.

FORAMINIFERAL LIMESTONES FROM NEW GUINEA.

Sir,—When reviewing the literature on some Foraminiferal limestones from New Guinea, during the preparation of a paper published in May last as No. 20 of a series of "Reports on the Collections made by the British Ornithologists' Union Expedition and the Wollaston Expedition in Dutch New Guinea, 1910–13", issued in 1916, I regret having overlooked an important contribution to the subject by my friend Mr. Frederick Chapman, the palæontologist of the National Museum at Melbourne, entitled "Description of a Limestone of Lower Miocene Age from Bootless Inlet, Papua" (Journ. Proc. Roy. Soc. New South Wales, vol. xlviii, pp. 281–301, pls. vii–ix, 1914–15). The forms of Foraminifera referred to by Mr. Chapman are almost identical with those mentioned in my report as occurring in the limestones of Mount Carstensz, and, moreover, the stratigraphical results are exactly similar in each case. It is interesting, therefore, to note that although these New Guinea localities are so widely separated, being probably some 600 miles apart, there is distinct palæontological proof that the limestones of both regions belong to the later Aquitanian stage of the Miocene epoch. It becomes increasingly difficult for the palæontologist to keep pace with the vast amount of literature which is issued on almost every branch of his subject, a condition of things which at the present time is more than ever accentuated on account of the Geological Society having discontinued the publication of their annual list of "Geological Literature", which has been of such inestimable service to all research workers in geological science.

R. Bullen Newton.

British Museum (Nat. Hist.),
South Kensington.

FEDERATED MALAY STATES.

Sir,—Owing to the fact that copies of the Geological Society's Proceedings have not been sent to me while residing abroad I have only just been made aware, by the appearance of No. 284 of the Quarterly Journal, that my name was unnecessarily introduced into the Discussion on a paper read on June 23, 1915, p. 622 (but only now printed and issued to Fellows, in February, 1917). The speaker, Mr. W. R. Jones, said that:—

"The danger of examining 'mountains under microscopes' was illustrated in a striking manner, in the case of a rock which occurs at the summit of Gunong Bakau, in the Federated Malay States. This rock was described as occurring extensively, and as being of no value. [A reference introducing my name is given here.—J. B. S.] It was further stated that the rock was evidence of the existence in this part of the granitic magma of a great quantity of free hydrofluoric acid capable of attacking felspar without the precipitations of a previously combined base, such as tin. Subsequently, however, the rock was found to contain tin-ore, and it has now been worked on a considerable scale."

As the Society's officers have published the above I will ask you to print the following brief reply.

The rock in question was *not described* as occurring extensively. It was described as being of no value because neither the quartz nor topaz was saleable. The passage concerning free HF omits any reference to the following condition in my publication: "if indeed it be correct to assume that the Chinchong rock is an alteration product." Tin-ore has not been found in the rock. The rock has not been worked.

The speaker's imperfect knowledge of the locality and failure to digest the page of my publication that he quotes have made him oblivious of dangers greater than that which he describes.

J. B. Scrivenor.

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ASSISTED BY

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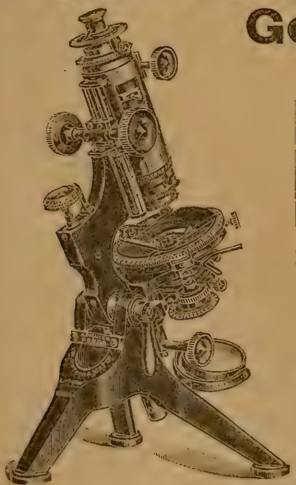


THE
GEOLOGICAL MAGAZINE
NEW SERIES. DECADE VI. VOL. IV.

No. IV.—APRIL, 1917.

ORIGINAL ARTICLES.

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

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

(*Continued from the February Number, p. 53.*)

(PLATE IX.)

A DEVELOPMENTAL sequence of *Membraniporellæ* showing progressive subordination of the ribbed front wall to a solid secondary front wall can be traced fairly directly from *Membraniporella pustulosa*, Bryd.,[1] which is prevalent in the zone of *M. cor-anguinum* and the *Uintacrinus* band and seems to die out in the zone of *Marsupites*. In the zone (restricted) of *A. quadratus* it is succeeded by

Membraniporella thoraciformis, sp. nov. (Pl. IX, Figs. 1–3.)

Zoarium unilaminate, incrusting.

Zoœcia of medium size, but very variable, average length from ·55 to ·7 mm.; the primary zoœcium is a simple form with a semicircular aperture surrounded by a thickened rim bearing a blunt median denticle, and an arched front wall arising just within slightly arched side walls and pierced by seven or eight pairs of short narrow slits; a prominent tubular secondary aperture is formed by general uprising of the margin of the aperture as in *M. pustulosa*, but the cavities which in that form are left on either side of the marginal denticle are closed in this species; at the same time a thin horizontal lamina extends from the lower side of the lower lip of the aperture some way downwards over the front wall, and this lamina and the tubular aperture combine to resemble very closely a throat and breast; at the same time the side walls swell and more or less completely coalesce.

Oœcia.—The immature and circumferential zoœcia have small, very globose oœcia, with an appearance of being perched on the margin of the aperture; as the secondary aperture develops it embraces the greater part of the oœcia, and its full development renders them very inconspicuous.

Avicularia accessory, small, bluntly mandibular, with arrowhead-shaped apertures crossed by a slender bar, placed at the lower side of the secondary aperture and generally leaning up against it in a slightly forward direction; they are very erratic in occurrence, as the figures show. Although this species appears to be most prevalent

[1] Geol. Mag., 1910, p. 483, Pl. XXXVI, Fig. 9.

at the top of the (restricted) zone of *A. quadratus*, it is very doubtful if it persists into the zone of *B. mucronata*. It seems to be succeeded in the base of the latter zone by the following species.

MEMBRANIPORELLA MANONIA, sp. nov. (Pl. IX, Figs. 4–7.)

Zoarium free or incrusting, multilaminate when free, generally multilaminate but occasionally unilaminate when incrusting.

Zoœcia of medium size but very variable, average length from ·55 to ·7 mm.: the primary zoœcia have semicircular apertures with a denticle on the lower lip and arched front walls arising from just within arched side walls and pierced by four or five pairs of long wide slits: the secondary aperture is formed as in the preceding species, but is rather contracted and keeps much lower, occupying a more or less central position in a gentle eminence, in the sides of which there are generally two but occasionally one or three rather smaller holes of irregular shape; the encroachment on the front wall by a thin horizontal lamina, which in the preceding species takes place only at the upper end, takes place in this species all round the front wall until in the older parts of the zoœcium only a small hole of irregular shape is left, at the bottom of which the front wall can hardly, if at all, be seen; the side walls coalesce and swell up to the general level, and the zoarium becomes an undulating expanse devoid of features except scattered holes, and resembling the surface of a Calcisponge such as *Manon*.

Oœcia.—There are practically no suggestions of oœcia among the peripheral zoœcia, and it is therefore improbable that they are represented by any of the holes which form the features of the mature zoœcia.

Avicularia are probably the origin of the holes accessory to the secondary aperture, although no ordinary avicularian structure is preserved in them; these avicularian holes occur usually in pairs beside the aperture, but one may be suppressed or a third added above the aperture; they lead to deep chambers. This species occurs very consistently in the lower part of the zone of *B. mucronata*, to which it seems a very reliable guide, in Hants and the Isle of Wight: no trace of it has yet been observed in any chalk that could be attributed to the zone of *A. quadratus*. All the figures represent segments of circular patches selected to show the passage from young to mature zoœcia.

MEMBRANIPORELLA TRANSLIGATA, sp. nov. (Pl. IX, Figs. 8, 9.)

Zoarium unilaminate, incrusting.

Zoœcia small, average length ·5 to ·6 mm.: the primary zoœcium was apparently of the same general type as in the two preceding species, the semicircular aperture having a very thick denticulated lower lip, from the lower side of which a broad process descends to a very short front wall arising rather deep within wide common side walls and pierced by three or four pairs of fairly wide slits and having generally a dwarfed appearance: this aspect passes rapidly, by a forward and upward thickening of the lips of the aperture and a general raising of the side walls and their throwing out lateral extensions over the front wall, into the secondary form; in this a more or less round, slightly tubular aperture, partly embracing and partly overshadowing the oœcium, occupies the summit of a considerable eminence which has a long gradual slope down to the front wall, a short steep slope, sometimes vertical or even apparently overhanging, down to the succeeding zoœcium, and two lateral ridges formed by a pair of avicularia with their beaks pointing inwards; the primary front wall is left at a considerable depth below the general surface, all except its solid backbone, which is raised to such an extent that it generally touches the secondary front wall at the foot and often unites with it, thus linking it to the secondary front wall at the head by a longitudinal bar; the apertures left on either side of this bar are quite small, and the ribbed parts of the front wall are generally quite out of sight.

Oœcia small and globose: as a rule they are wholly enveloped in the eminence formed round the secondary aperture, but Fig. 9 illustrates a specimen in which this eminence has not been fully developed throughout and oœcia are partially visible here and there.

Avicularia very regularly present in pairs below and at the side of the aperture, appearing as swellings bearing on their outer slopes small elongated beaks with arrowhead-shaped apertures: these swellings roof in chambers which go down to the back wall, thus producing the typical Steganoporellan structure; unpaired avicularia may occur irregularly in other positions. This species occurs in the Norwich and Weybourne Chalk, and persists into the Trimingham Chalk, where it becomes scarce. It has a very considerable general resemblance to some forms of *Membraniporella castrum*, Bryd.,[1] from which it is readily distinguishable by the much greater length of uncovered front wall and the cavity just below the edge of the secondary aperture possessed by the latter.

MEMBRANIPORELLA PYRAMIDALIS, sp. nov. (Pl. IX, Figs. 10–12.)

This species is so closely akin to *M. transligata* that it can be best described by enumerating the points in which they differ. In this species the zoœcia are larger, the average length being from ·6 to ·7 mm.; the overlap of the primary front wall by the secondary one is more extensive; the primary front wall has much more slender ribs and looks decadent; there is only a single cavity of irregular but on the whole semicircular shape in the secondary front wall, as the primary front wall is never attached to it and is almost always wholly out of sight; the paired avicularia are similar internally, but externally are largely embraced by the apertural prominence, while the beaks stand out more and are longer, the points often impinging on the aperture, and very sharply defined, and give the apertural prominence the appearance of a pyramid, to which they contribute the angles.

This species is only known to me from the Trimingham Chalk. It has attained an almost Steginoporid structure by a route so wholly un-Steginoporid that another step along it could hardly fail to result in the total suppression of the Cribrilinid front wall and the

[1] GEOL. MAG., 1909, p. 398, Pl. XXII, Figs. 4, 5.

development—by completion of the secondary front wall—of a purely Lepralian form with Steganoporellan structure.

EXPLANATION OF PLATE IX.

(All figures × 12 diams.)

Fig. 1, 2.	*Membraniporella thoraciformis.*	Shawford, Hants.
,, 3.	,, ,,	Portsdown, Hants.
,, 4–7.	,, *manonia.*	Portsdown, Hants.
,, 8.	,, *transligata.*	Coltishall, Norfolk.
,, 9.	,, ,,	Trimingham.
,, 10–12.	,, *pyramidalis.*	,,

II.—On the Integument of *Iguanodon bernissartensis*, Boulenger, and of *Morosaurus becklesii*, Mantell.

By Reginald Walter Hooley, F.G.S.

(PLATE X.)

Integument of *Iguanodon bernissartensis*.

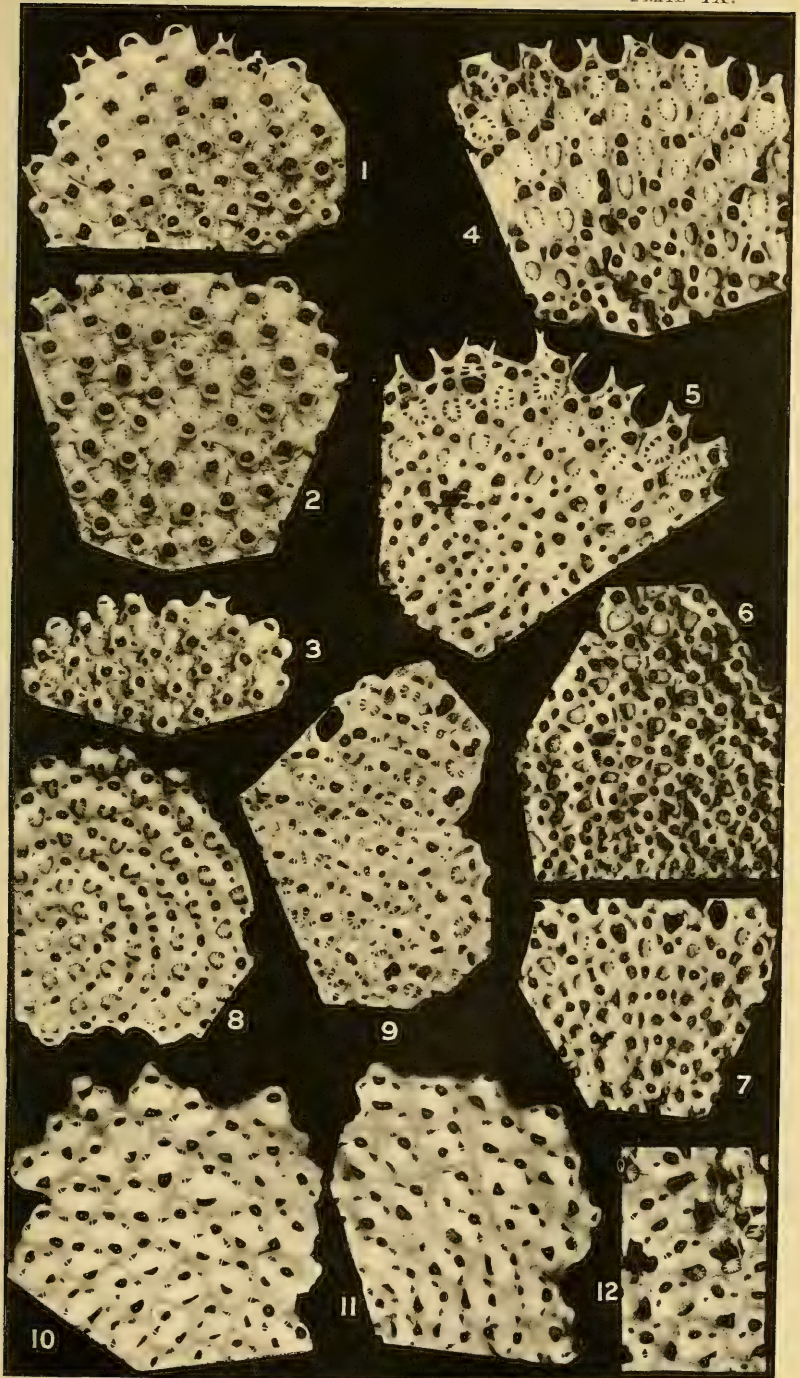
THE *Iguanodon* has been known since 1825, when the genus was first described from teeth by Mantell.[1] Odd bones and various associated portions of the skeleton have been found in England, and in 1878 the skeletons of many individuals were discovered in the Wealden of Bernissart, near Mons, Belgium.

No trace of the dermal covering has hitherto been observed. Owen[2] in 1885, when describing the bones of a "young *Iguanodon*" from the Wealden of the Isle of Wight, mentions that "some portions of a layer of dark finely granulated carbonaceous matter were found embedded between the ribs, near the middle of the side of the trunk", which he queried as the integument of *Iguanodon*, but these remains were proved later to belong to *Hypsilophodon*.

In 1914 I obtained from the Wealden Shales of Brighstone Bay, Isle of Wight, nearly the entire skeleton of a young individual of *Iguanodon bernissartensis*, with the exception of the greater part of the tail.

In July last, while clearing away the matrix from the preacetabular extremity of the left ilium, a portion of the epidermis (Fig. 1) was exposed. It covers an area 90 mm. long by 40 mm. wide. The impression of the integument is also discernible on another block 78 mm. long by 57 mm. wide, found in close proximity to the other. Fragments of skin were also discovered underlying two of the left thoracic ribs. On these latter specimens carbonaceous matter is to be seen. No scutes or dermal ossifications were found. The skin is remarkably thin, and covered with small convex tubercles varying in diameter from 5 mm. to 3 mm. On the largest specimen there is an area, 8 mm. by 7 mm., where the tubercles are slightly larger and flatter, and 65 mm. distant occurs another patch with the same measurement, where the tubercles coalesce in such a manner that the tuberculation is almost invisible. The tubercles on the edge of the skin at the top

[1] G. Mantell, Phil. Trans., 1825, p. 184.
[2] R. Owen, Mon. Foss. Rept. Weald. Form., pt. ii, 1855, p. 51.



R. M. Brydone, Photo. Bemrose, Collo.

Chalk Polyzoa.

of Fig. 1 are also decidedly larger and flatter than the others. One plate-like tubercle, 10 mm. in diameter, occurs on the smaller portion of the skin from the same inguinal region. It appears therefore probable that on those parts of the body exposed to the sun large flat tubercles would be found as in *Trachodon annectens*,[1] and it is evident that the "ground plan" of the epidermis is essentially similar, consisting of small, rounded tubercles, although in *Iguanodon* they are not so rounded or apical. Professor Osborn[1] thought that the iguanodonts from the Lower Cretaceous of Europe would probably be distinct in their "epidermal covering" from the trachodonts of the Upper Cretaceous of America, and it is interesting to find that at least they are alike in ground plan.

INTEGUMENT OF *MOROSAURUS BECKLESII*, MANTELL = *M. BREVIS*, OWEN.

An impression of the epidermis of this reptile (Fig. 2) is well displayed on a block of rock removed from the hollow between the radial crest and the inner border of the left humerus. This humerus, with the radius and ulna, was found in the Wealden beds of Hastings by S. H. Beckles in 1852. These specimens (No. R. 1870) are now in the British Museum. They were referred to by Mantell in a lecture given by him at the Royal Institution in that year. The report[2] of the lecture records that "A portion of the scaly cuirass which covered the limbs and is composed of hexagonal plates was exhibited". The integument was also noticed by Marsh,[3] when examining this fossil while still in the possession of its discoverer. He remarks that he "found attached to the humerus portions of the osseous dermal covering, the first detected in the *Sauropoda*, and known only in the present specimen". It has not been further described, but by kind favour of Dr. A. Smith Woodward I am now privileged to give the details.

The side of the matrix upon which the epidermal markings are shown is convex, well seen in Fig. 2, but this feature is entirely due to the concavity of the particular area of the humerus upon which it lay and not to the natural rotundity of the limb. There was no intervening matrix between the skin impression and the bone, therefore unless this portion of the integument was turned inside out after the decomposition of the muscles and before the matrix was deposited upon it, the under surface of the epidermis is exhibited. The only fact that supports the improbable theory of the reversal of the integument is that there is an apparent ornamentation of very small rounded tubercles displayed on some of the plates. The smallest plates, especially at the upper end of the specimen, are covered with them. It does not appear that they are due to oxidization subsequent to the removal of the block from the humerus. I have observed a somewhat similar result from chemical action after exposure to the atmosphere on matrix which at first had a smooth surface. However, it is more probable that they are papilliform

[1] H. Osborn, Mem. Amer. Mus. Nat. Hist., N.S., vol. i, pt. ii (June, 1912), pp. 46, 47.
[2] Proc. Roy. Inst., vol. i, p. 34, 1852.
[3] O. C. Marsh, GEOL. MAG. [3], pp. 205, 206, 1889.

protuberances of the epidermis into the dermis and that we are looking upon the inner surface of the former.

There is no sign of ossification, although Marsh[1] speaks "of the osseous dermal covering". The extent of the epidermal impression is 210 mm. long by 200 mm. wide. It consists of hexagonal plates, convex and boss-like, which on their outer surface were probably flat. A group comprising eight of the largest plates covers an area 95 mm. long by 68 mm. wide. The central plate of this group has a diameter of 26 mm. The plates surrounding this cluster gradually decrease in size, until they are only 9 mm. in diameter. The plates do not overlap. The integument of *Morosaurus becklesii* was tuberculate and the lessening in dimensions of the tubercles towards the axillary surface of the arm, where they probably became smaller and rounded, is after the manner of *Trachodon* and *Iguanodon*.

EXPLANATION OF PLATE X.

FIG. 1.—Impression of a portion of the epidermis from the left ilium of *Iguanodon bernissartensis* obtained by the author from the Wealden Shales of Brighstone Bay, Isle of Wight, in 1914.

,, 2.—Impression of a portion of the epidermis of *Morosaurus becklesii*, Mantell, found by Mr. S. H. Beckles in 1852 in the Wealden beds of Hastings, now in the British Museum (No. R. 1870).

III.—PICRITE FROM THE AMPWIHI RIVER, MOZAMBIQUE.

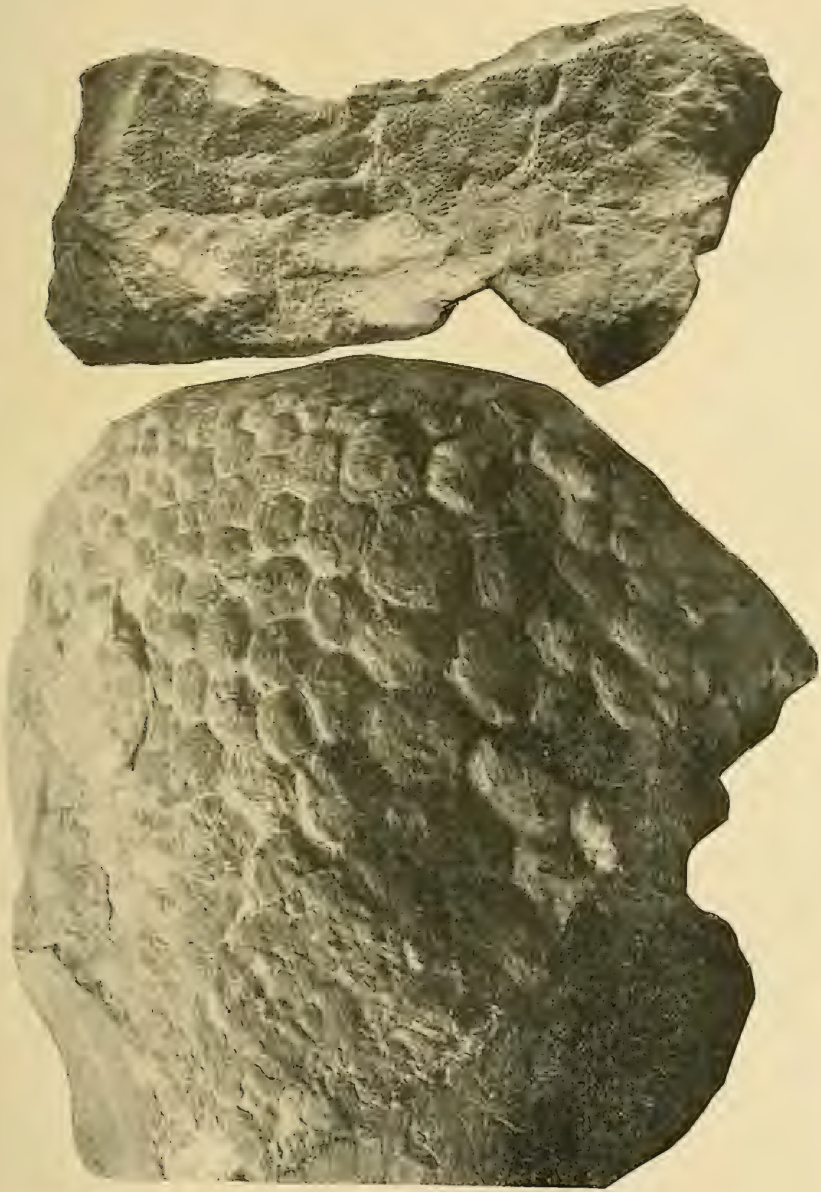
By ARTHUR HOLMES, A.R.C.S., D.I.C., B.Sc., F.G.S. (with an Analysis by H. F. HARWOOD, M.Sc., Ph.D.).

(PLATE XI.)

ALMOST due west of Mozambique Island, at a distance of about forty-two miles from the sea, the military road from Mosuril to Nampula crosses the Ampwihi River, an important tributary of the Monapo.[2] During the dry season the stream is reduced to a string of stagnant pools, separated by long reaches of sand and gravel that here and there are interrupted by outcrops of the underlying formations. Throughout the greater part of its course the Ampwihi flows through a region in which gneisses persist with monotonous regularity, the only variation being that due to occasional intrusions of granite and of still later pegmatite dykes. At the point where the military road crosses the narrow channel a welcome diversion is introduced by the presence of a dark compact dyke about 10 feet in thickness. The dyke appears on the right-hand bank and crosses obliquely to the other side, taking a N.N.W.–S.S.E. course across the strike of the older rocks. Upstream, about seventy yards to the south-east, the Ampwihi bends to the south-west, so that it returns towards the dyke, which is again exposed across its sandy floor. The dyke was traced by Mr. E. J. Wayland in July, 1911, for a distance of altogether 200 yards, and was examined by Mr. D. Alex. Wray and later by myself during the same year. It is clearly the latest

[1] O. C. Marsh, op. cit., p. 206.

[2] See A. Holmes & D. A. Wray, "Mozambique: a Geographical Study": *Geog. Journ.*, p. 143, Aug. 1913 (Map, p. 112).



PORTIONS OF INTEGUMENT OF WEALDEN DINOSAURS.

rock of the district, and is intruded along a line of fault, for in two cases pegmatite dykes seen on the eastern side are broken across and reappear on the western side with a well-marked northerly displacement.

Petrography.

The specimens collected were from the margin—evidently chilled—of the transverse dyke, and have a dark-grey colour, mottled with nearly black glassy phenocrysts of olivine. Here and there are minute white amygdales, the infilling consisting of an isotropic material that is probably glass. The weathered surface is creamy grey in colour with rusty patches corresponding to the phenocrysts. The average specific gravity of three fragments of the fresh rock is 3·08.

In thin section the rock is found to consist of corroded phenocrysts of olivine in a fine-grained groundmass composed mainly of elongated grains of augite and enstatite, the former alternating with and sometimes intergrown with laths of soda-lime felspar. In places interstitial patches of pale brownish-grey glass appear, and where a minute amygdale is seen it is found to be composed of the same obscure material (Pl. XI, Fig. 1).

The *olivine* phenocrysts are occasionally hyp-idiomorphic in outline, but generally they are deeply corroded, the resorption having sometimes divided a large crystal into a number of rounded fragments. Except around the edges and along cracks and cleavage planes, where serpentinization has begun, the crystals are still quite fresh. The serpentine is mainly of the fibrous variety, chrysolite, the fibres being arranged normally to the edges or cracks from which the alteration has developed. The only inclusions present are sparsely scattered grains of magnetite. In one section it was noticed that a shred of biotite had developed at the junction of an olivine crystal with interstitial glass.

The most abundant mineral of the groundmass, and indeed of the whole rock, is a pale yellow-green *augite* occurring in granules that are generally slightly elongated along the c axis. The average refractive index is 1·7; the optic-axial angle is low; and the specific gravity is nearer 3·2 than 3·1. These characters, when considered in relation to the chemical composition of the rock, indicate that the pyroxene approximates to the enstatite-augite variety.[1]

Among the augite granules there occur a few colourless grains generally of similar average dimensions, but occasionally slightly larger, having noticeably lower refractive index and double refraction, and giving straight extinction. They were at first thought to be wollastonite, but further optical examination showed that the optical character is positive and that the average refractive index is about 1·67. These properties lead to the conclusion that the mineral is *enstatite*. It is clear from its relations to the surrounding minerals that it crystallized after olivine and before augite. In Pl. XI, Fig. 2, a good example of enstatite can be seen adjoining the dark space on the right-hand side.

[1] See J. V. Elsden, Q.J.G.S., vol. lxiv, p. 287, 1908.

Between the grains of augite another colourless mineral, with prismatic habit, occurs. The optical characters indicate that it is a soda-lime felspar, approaching bytownite in composition. The average refractive index is about 1·57, and the maximum extinction angle is 40° measured from the direction of elongation of the microliths. As the specific gravity is estimated to be about 2·73, the composition of the felspar is approximately Ab_{30} An_{70}, i.e. that of a *calcic labradorite.*

The relations between augite and felspar are illustrated in Pl. XI, Fig. 2. A casual glance would suggest that the augite crystallized before the felspar, but this appearance is due to the superior relief of the augite, and a careful examination shows that the two minerals crystallized together. This conclusion is corroborated by the fact that in places a micrographic intergrowth can be detected. The augite grains become more angular, and between them the minute interstitial labradorite can be traced in optical continuity from place to place. On the borders of the micrographic areas the felspar frequently becomes fibrous and tends to radiate.[1] Becoming gradually more obscure the fibrous felspar dies away and an interstitial clearing of glass appears. The refractive index of the glass is 1·55, and its specific gravity is 2·5, indicating approximately the composition of syenite.[2]

The relative proportions of the minerals were measured by the Rosiwal method. Under a 1 in. objective the proportions of olivine and groundmass were determined, and afterwards the groundmass was analysed under a $\frac{1}{4}$ in. objective. As it was not found possible to distinguish in every case between augite and enstatite, the two pyroxenes were estimated together.

In order to determine the specific gravities of the various minerals, a diffusion column of methylene iodide and methylene iodide diluted with benzine was prepared so as to give a range from 3·3 to 2·3. Olivine and magnetite sank. A well-marked band of pyroxene formed between 3·1 and 3·2. Another band formed at 2·73 (labradorite), tailing out above and below owing to the difficulty of obtaining a clean separation from such fine-grained material. Finally, another layer formed at the level corresponding to 2·50.

The results obtained are as follows:—

Mineral.	Percentage by Weight.	Specific Gravity.
Glass . . .	8	2·50
Labradorite, An_{70} .	17	2·73
Pyroxene . . .	45	3·15 (average)
Olivine . . .	29	3·45 (?)
Magnetite . . .	1	5·17 (?)
Total . .	100 Average .	3·20

The actual specific gravity of the rock is 3·08, so that the figure assumed for olivine, 3·45, is probably a little too high. As the

[1] See Iddings, *Rock Minerals*, 2nd ed., fig. 28, p. 215, 1911.
[2] See J. A. Douglas, Q.J.G.S., vol. lxiii, p. 153, 1907, for relations between refractive indices and specific gravities of glasses.

analysis indicates that the composition of the olivine includes nearly 80 per cent of forsterite, the specific gravity should be about 3·4. This figure would give for the rock a calculated specific gravity of 3·10, which agrees more closely with the observed result.

Chemical Composition.

An analysis of the rock was made by Dr. H. F. Harwood, with the following results:—

	Percentages.	Molecular Proportions.	Mineral Composition (Norm.).	
SiO_2	46·37	0·773		
Al_2O_3	10·82	0·106	Orthoclase	3·33
Fe_2O_3	1·60	0·010	Albite	8·38
FeO	7·85	0·109	Anorthite	23·33
MgO	20·78	0·5195		
CaO	7·94	0·142	Diopside	12·82
Na_2O	0·99	0·016	Enstatite	16·41
K_2O	0·57	0·006		
H_2O+	1·97	—	Olivine	30·30
H_2O-	0·82	—		
CO_2	none	—	Magnetite	2·44
TiO_2	0·13	0·002	Ilmenite	0·30
P_2O_5	none	—		
MnO	0·16	0·002		97·36
Cr_2O_3	0·07	0·0005	Water	2·79
NiO	0·07	0·001		
Total	100·14		Total	100·16

Specific gravity (average of three specimens) = 3·08.
Radium content (A. H. 1915) = $0{\cdot}44 \times 10^{-12}$ grams per gram of rock.

The composition of the rock is of a type not very commonly found. Its nearest analogue is that of a Hawaiian picrite-basalt which was erupted in 1840.[1] A few other similar analyses are cited in the table below (p. 154), from which it may be seen that two British rocks, one from Anglesey and one from Loch Garabal, have a general chemical similarity to the picrite under discussion. The presence of nickel and chromium in every case in which it has been sought for is an interesting feature, and indicates the importance of making analyses as complete as possible. The association of these elements with olivine-rich rocks has been frequently pointed out,[2] and there is no doubt that by determining such relations in detail much may yet be learned concerning the genesis of igneous rocks and ore-deposits. Among African rocks the Mozambique picrite resembles most closely some of the mineralized picrites of the Insizwa Range.[3] Owing to the presence of pyrrhotite and of copper and nickel sulphides in these rocks the analyses cannot be directly compared, but it is clear that

[1] W. Cross, Prof. Paper 88, U.S.G.S., 1916, pp. 44, 77. The mineralogical composition of the Puna lava of 1840 is almost identical with that of the Ampwihi picrite.

[2] H. S. Washington, Trans. Ann. Inst. Min. Eng., xxxix, p. 735, 1908.

[3] W. H. Goodchild, "Economic Geology of the Insizwa Range": Inst. Min. and Met. (read December 21, 1916).

the two rock-types are very similar. In one case (sample No. 7) Mr. Goodchild remarks: "The felspars not infrequently show micrographic intergrowth with the pyroxene, but on the whole are interstitial," and in the photo-micrograph of the rock (Fig. 9) it can be seen that the correspondence in texture goes even further, for the olivines are markedly porphyritic. From nickel-bearing rocks we may turn to chromium-bearing rocks, as exemplified by those of the Great Dyke of norite of Southern Rhodesia.[1] Here, however, the picrites are coarse-grained, and are not comparable in detail, either texturally or mineralogically, with the Ampwihi picrite.

	A.	B.	C.	D.	E.
SiO_2 .	46·37	47·25	47·75	42·87	46·0
Al_2O_3 .	10·82	9·07	10·56	10·93	6·8
Fe_2O_3 .	1·60	1·45	0·74	3·44	3·0
FeO .	7·85	10·41	8·34	10·14	7·5
MgO .	20·78	19·96	19·09	16·27	23·9
CaO .	7·94	7·88	9·62	9·11	8·1
Na_2O .	0·99	1·38	1·32	0·92	0·8
K_2O .	0·57	0·35	0·12	0·13	0·9
H_2O+ .	1·97	0·04	2·06	2·87	} 2·4
H_2O- .	0·82	0·08	0·05	0·57	
CO_2 .	none	—	—	2·70	n. d.
TiO_2 .	0·13	1·61	0·37	tr.	n. d.
P_2O_5 .	none	0·21	0·03	tr.	n. d.
MnO .	0·16	0·13	0·10	tr.	n. d.
Cr_2O_3 .	0·07	0·13	0·24	n. d.	0·2
NiO .	0·07	0·12	0·07	n. d.	n. d.
Total .	100·14	100·03	100·46	99·95	99·60

A. Picrite. Ampwihi Crossing, Mozambique (an. Harwood).
B. Picritic basalt. Flow of 1840, Nanawale, Puna, Hawaii (an. Steiger).
C. Diabase? Cathay Hill, Mariposa County, California, U.S.A. (an. Hillebrand).
D. Hornblende picrite. Ty Crœs, Anglesey (an. Phillips).
E. Peridotite? Loch Garabal, Scotland (an. Player).

Returning to the analyses cited above, there are three further relationships worthy of discussion, namely, the relation of the MgO/FeO ratio to the percentage of alumina, the association of potash with magnesia, and that of soda with iron-oxides.

Vogt has shown that in peridotites the ratio of MgO to FeO increases on an average as the percentage of alumina decreases.[2] For percentages of alumina between 10 and 11 the atomic ratio of MgO/FeO averages 2·6. In the Ampwihi picrite there is considerable divergence from this value, the ratio being 4. There is a similar divergence in the case of the Cathay Hill Diabase, the ratio of which is 3·8. The three other rocks cited, however, give ratios that agree very well with Vogt's generalization:—

	D.	B.	E.
Al_2O_3	10·93	9·07	6·8
Atomic ratio MgO/FeO .	2·2	3·0	4·2

[1] A. E. V. Zealley, Trans. Roy. Soc. S.A., p. 14, 1915.
[2] See A. Harker, *Natural History of Igneous Rocks*, p. 373, 1909.

Washington has recently pointed out the general sympathetic relation between potash and magnesia, and between soda and iron oxides in igneous rocks.[1] The former relation is exemplified with one exception (C) by the analyses quoted :—

	E.	A.	B.	C.	D.
MgO .	23·9	20·78	19·96	19·09	16·27
K_2O .	0·9	0·57	0·35	(0·12)	0·13

indicating that the Ampwihi picrite is not different from its analogues in this respect.

The soda-iron relationship does not hold within the narrow limits of the five analyses A–E. If soda and potash be compared with the MgO/FeO atomic ratio, however, it will be noticed that with one exception in each case potash increases, while soda decreases, with the ratio.

Atomic ratio of	E.	A.	C.	B.	D.
MgO/FeO .	4·2	4·0	3·8	3·0	2·2
K_2O . . .	0·9	0·57	(0·12)	0·35	0·13
Na_2O . . .	0·8	0·99	1·32	1·38	(0·92)

It may not appear that there can be any meaning in such results as these, drawn as they are from rocks without apparent genetic relations in either time or place. Such rocks may, neverthless, have genetic relations in virtue of the processes by which they were formed. By comparing similar igneous rocks, correspondences and discrepancies of the kind to which attention has been drawn may come to be used, when their significance is understood, to suggest the origin and differentiation of the magmas from which the rocks have crystallized. It is possible that magnesia-rich magmas do not readily part by crystallization with their potash, and that they may selectively absorb and accumulate potash from the rocks through which they pass in approaching the surface. Similarly, in proportion to their iron content, magmas may not readily part by crystallization with their soda, and they may selectively absorb and accumulate soda from the rocks through which they pass on their upward or lateral journeys. This digression has led us far from the picrite dyke of the Ampwihi River, to which we must now return to pick up afresh the lines of thought suggested by analytical results.

The radium content of the rock, only $0{\cdot}44^{-12}$ grams per gram, is very low. Peridotites appear to average more than this amount, a composite analysis of ten varieties giving $0{\cdot}51 \times 10^{-12}$ grams per gram.[2] Two dunites analysed for radium by Professor Strutt, however, gave $0{\cdot}33^{-12}$ and $0{\cdot}34^{-12}$ grams per gram respectively.[3] The slightly higher result for the picrite is probably due to the presence of felspathic constituents, which are generally far richer in radium than olivine or enstatite. The result is of more than numerical interest merely, for it shows that the dyke cannot have

[1] Proc. Nat. Acad. Sci., p. 574, 1915.
[2] A. Holmes, *Science Progress*, 1914, No. 33, p. 16.
[3] R. J. Strutt, Proc. Roy. Soc., 1906, A. 77, p. 479.

derived its felspathic constituents by any process of absorption. Had this been the case the radium content would undoubtedly have been higher.

Cooling History.

The order of crystallization has already been indicated in the description of the various minerals. It may be summarized as follows: (*a*) magnetite; (*b*) olivine, afterwards partly resorbed by the magma; (*c*) enstatite; and (*d*) augite and calcic-labradorite; leaving (*e*) a residuum of glass.

This cooling history is of particular interest since it is closely paralleled by that of one of the artificial melts described by Andersen in his paper on the Anorthite-Forsterite-Silica System.[1] The ternary diagram (fig. 9, p. 437, op. cit.) represents the cooling history of any melt containing only the three constituents mentioned. The melt chosen for comparison has a composition equivalent to 60 per cent of forsterite, 15 per cent of silica, and 25 per cent of anorthite. This mixture is expressed in the ternary diagram by a point which lies well within the forsterite field of crystallization. Forsterite is therefore the first mineral to crystallize, and it continues to do so until the falling temperature brings the system to the boundary-line between the fields of forsterite and clino-enstatite. When this line is reached 37 per cent of forsterite has crystallized. Now, however, the further evolution of the system proceeds along the boundary-line in such a way that clino-enstatite is separated, while forsterite is slowly resorbed by the liquid. Ultimately a point is reached between the clino-enstatite and anorthite fields of crystallization, and at this stage 21 per cent of clino-enstatite has crystallized, while the forsterite has been reduced to 34 per cent. During the completion of the crystallization the temperature continues to remain constant. More forsterite is resorbed, reducing its percentage to 25, while clino-enstatite and anorthite crystallize out together, the final proportions of these substances being 50 per cent and 25 per cent respectively.

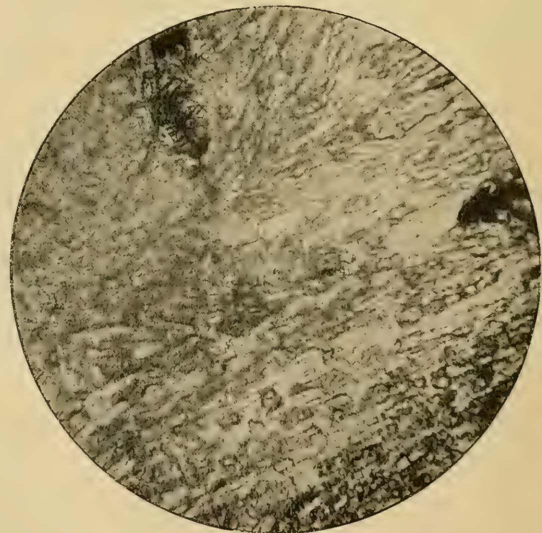
In the picrite described in this paper the actual minerals are analogous to those of the artificial melt. Instead of forsterite we have olivine, of which about 80 per cent is forsterite; instead of clino-enstatite we have enstatite, followed by enstatite-augite; and instead of anorthite we have a calcic-labradorite containing about 70 per cent of anorthite. The percentages are also very similar, being approximately in the proportion 30 : 40 : 30, instead of 25 : 50 : 25. In an artificial melt of the former composition the ternary diagram shows that the cooling history would be the same as in that outlined above. The crystallization of the picrite was, of course, relatively complicated by the presence of iron and alkalies, but these do not appear to have appreciably affected the salient features of the cooling history. The rock itself, as portrayed by the

[1] Olaf Andersen, *Amer. Journ. Sci.*, xxxix, p. 407, 1915 (see in particular figs. 9 and 11 and table viii).

1

× 25

2.



× 25

PICRITE FROM MOZAMBIQUE.

photographs of Plate XI, gives visual proof that the same course was followed as in the artificial melt. It should, however, be mentioned that part of the soda-lime felspar probably enters into the crystal framework of the augite, while another part may remain hidden in the residual glass. The presence of a minute reaction rim of biotite between olivine and the glass further suggests that the latter may contain the constituents of orthoclase. Consequently the actual amount of felspar in the rock is less than that calculated from the analysis, while the pyroxene appears to be correspondingly more abundant.

In conclusion, I wish to express my thanks to Dr. H. F. Harwood for his collaboration in making the analysis, and to Mr. G. S. Sweeting for taking the micro-photographs with which the paper is illustrated.

EXPLANATION OF PLATE XI.

Fig. 1.—*Picrite* from the Ampwihi River, Mozambique. Corroded phenocrysts of olivine, serpentinized along cracks, are seen in a fine-grained groundmass. × 25 diameters.

,, 2.—*Groundmass* of picrite from the Ampwihi River, showing grains of augite lying amongst parallel or radiating laths of labradorite. In places the two minerals show graphic intergrowth. On the right-hand side a rounded crystal of enstatite of earlier crystallization than the rest of the groundmass can be seen. × 125 diameters.

IV.—Disturbed Gravels.

By R. M. Deeley, M.Inst.C.E., F.G.S.

There are many features characterizing the surface portions of deposits which are very puzzling. Indeed, the more one studies them the less one is inclined to be dogmatic. Many true glacial deposits show remarkable signs of disturbance throughout their mass. We may instance the Contorted Clay of Norfolk as a case in point. Even when boulder-clays are too uniform in texture to show signs of movement they are often kneaded into the rocks upon which they rest, and rocks of all ages often show such disturbances when they have been overridden by ice. Here we are dealing with the results produced by the action of forces operating from without the deposit.

In other cases, as I have attempted to show,[1] the effects can be accounted for in the supposition that we have heavy beds of gravel or gravelly clay sinking into soft lighter clays or marls below. The trail and underplight of Spurrel seems to be caused by such movements.

There are disturbances, however, which it seems to be impossible to account for in this way. I refer to the peculiar signs of movement shown by gravelly and sandy deposits, even when they lie outside the areas which we know to have once been covered by ice-sheets. They are to be seen in many of the gravels and sands of the South of England, and also in river gravels, which there is reason to

[1] Geol. Mag., 1916, pp. 2–5.

suppose have never been covered by glacier ice, even when occurring within the glaciated areas. When studying the deposits of the Trent Basin[1] I was very much interested in these surface features. They were never seen in the low-lying gravels; but always very marked in those resting with their upper surfaces 25 feet or more above the alluvial plain. That they were due to the action of ice in some form or other seemed the only possible explanation. At that time, and indeed until I had seen some of the Thames gravels, the most likely theory of their formation seemed to be the movement over them of glacier ice for very short periods of time. This seemed to be supported by the trend of the axes of the disturbances, which was almost, if not always, such as to indicate a movement down the valleys.

Another peculiar feature of these surface disturbances in the Trent Basin deserves notice. In this area we have fluvio-glacial gravels of two very different lithological characters. The one was formed by ice which came from the west, and is destitute of flints where undisturbed. The other contains flints throughout, having an easterly origin. For the flints to penetrate several feet deep into the flintless deposit was a great difficulty, and seemed to require the operation of a force acting from without.

If ice in glacier form be out of the question on the south side of the Thames Valley, another explanation must be looked for. The explanation about to be proposed requires further field work before it can be accepted as correct; for it is necessary that what is now going on in very cold climates should be more carefully studied.

Fig. 4, p. 471, in my paper on the Pleistocene Deposits of the Trent Basin,[2] shows a typical form of the phenomenon. Here we have rising up towards the surface waves composed of very complex masses of sand and gravel. Between these waves lie deposits of more sandy material containing pebbly festoons and streaks. At their bases the "waves" consist of the disturbed gravel and sand beds below; but as we rise the deposit becomes less and less stratified and finally loses all signs of stratification. The material between the waves of gravel is quite sandy and shows traces of very irregular bedding. It is remarkably like a rainwash we should expect to be derived from the gravel, and it retains this character even when the pockets penetrate as much as six feet into the hollows between the waves. But how can we account for rainwash in such a position? The sides of the gravel waves are too steep for them to have existed without the rainwash in their troughs.

The phenomena we are dealing with may have been formed in the following manner during periods of intense cold. During the summer the whole mass thaws, and the water-level in the gravel lies five or six feet below the surface. In the winter the frost penetrates the gravel, but does not disturb it until the water-level is reached. As the water freezes the ice expands sideways as well as vertically. But it is not free to expand horizontally everywhere. Imagine that it expands over definite areas and that crushing takes place on the

[1] "The Pleistocene Deposits of the Trent Basin": Q.J.G.S., 1886, pp. 437–79.

[2] Q.J.G.S., 1886.

margins of these areas, and that when crushing goes on the deposit rises and raises ridges on the surface of the ground. We should then have on the surface of the ground a complicated series of ridges with numerous hollows between them. During periods of thaw the finer material would be washed into these hollows.

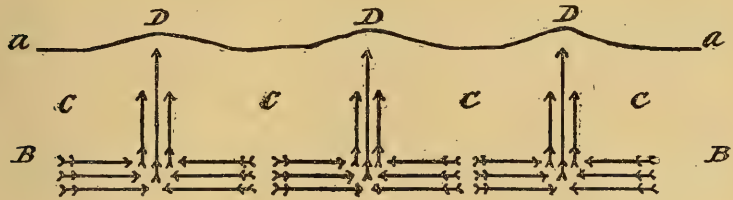


Fig. 1 shows diagrammatically how this process is supposed to take place. A A is the ground-level and B B the water-level in the gravel and sand. When the frost reaches the water-level expansion takes place and there is movement in the direction shown by the arrows. Below the points marked D the gravel and sand rise and ridges are raised on the ground surface; when thawing occurs the loose material of the ridges is washed into the hollows. We thus have the material rising at D D and sinking areas at C C C. Eventually troughs of rainwash form at the points C and gravel waves below the ridges D.

It is possible that when once lines of weakness had been formed in the gravel below the surface, crushing generally goes on along the same lines each winter, and that rainwash collects in the same hollows each summer. A repetition of this process results in the formation of waves of gravel separated by troughs of rainwash. Much would depend upon the water-level in the gravel and the direction of the water circulation in the gravel. It may be that the waves and troughs tend to arrange themselves parallel with the direction of the underground flow.

If such an explanation be the true one, we should expect to find such ridges and hollows on the surface of gravel deposits in Arctic regions. Various patterns have been noticed on the surface of the ground in high latitudes, and it would be well to examine them very carefully.

Any surface stones or flint implements resting on or near the surface would, if the above theory be correct, get buried deep in a deposit with which they are not contemporaneous. In some such way flints have been buried five or six feet deep in deposits which did not originally contain flints; indeed, it has always seemed surprising how foreign articles have managed to bury themselves so deeply even in gravelly deposits. It is necessary in all cases to make sure that flint implements are in undisturbed bedded gravels and sands; for if they are not they may have been introduced long after the deposit was formed.

V.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

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

Foreword.

DURING the past seven years I have published several papers based upon preliminary investigations on the anatomy of the Holectypoida, an order of the Euechinoidea which, by general consent, is regarded as transitional between the Regular and Irregular sections of the class. Continued study, aided by increased mental and technical experience, has revealed an ever-increasing number of interesting features in the order, and has made possible more definite and confident surmises as to its affinities with other groups. The series of contributions here commenced is intended to amplify, and in some cases to correct, the statements made in my earlier papers. With very few exceptions the actual descriptions that are given in the former work still seem to be essentially correct, but every fresh examination, even of the same specimens, testifies to the incompleteness of most of the observations hitherto published. New material, better or differently preserved, often draws attention to features overlooked or discarded as unimportant in the examples already studied. No apology is needed for the publication of incomplete descriptions of natural objects, since complete knowledge is as yet nowhere attained. When inaccuracies of observation have been detected, their nature and cause will be stated frankly, accompanied, verbally or not, by suitable contrition.

But in matters of theory—the tracing of phyletic series and of the trend of structural evolution—the contrast between my present views and those previously held and expressed is likely to appear more marked. A structural feature overlooked or misunderstood may be added to, or modified in, a description without seriously altering the whole; but when the corrected knowledge is applied to a theory, it may produce a veritable revolution. Nevertheless, if the formulation and publication of theoretical conclusions were to be postponed until a basis of complete knowledge is attained, science would speedily sink into a state of encyclopædic chaos, without so much as an alphabetical classification in which to wrap its disjointed facts. Much of the progress of science is achieved by reasoned attacks upon established theories, and if it is legitimate and profitable to demolish the flimsy edifices of others, it is surely less invidious and more seemly to treat similarly the product of one's own imperfect efforts. So that it will be with joy in the new and better building, rather than with regrets and apologies for the earlier erections, now obsolete and superseded, that the fresh theoretical opinions will be raised. To suggest that the new theories are correct in detail would be ridiculous, but they are more securely founded than the former ones, and can yield place only to a better series, based upon more complete knowledge.

I have chosen the serial method of presenting my results, partly on account of their bulk, and partly because the aspects of the

Echinoidea covered by my researches are so various that some sections will be independent, in all but their ultimate aim, of the actual order Holectypoida. Much of the work is concerned with recent forms (partly with their histology), some deals entirely with fossil genera and species, and some is largely stratigraphical in treatment. It is obvious that such diverse sections will affect workers in very different spheres, who will not wish to be burdened with a cumbrous mass of details which have no direct bearing on their particular branch of study. Glory and honour accrue to the author of a massive tome, but understanding and gratitude are the reward of the writer of pamphlets.

As far as possible it is intended that the earlier sections of the work shall deal with matters of fact and observation, so that the theoretical conclusions derived from them may be concentrated into the later parts, and be more or less synchronous in their appearance and homotaxial in their expression. I hope to publish the shorter sections (or those of them that deal with subjects of a palæontological or geological character) in this Magazine, in continuation of the earlier series, most of which appeared here. Larger, or purely zoological, sections will necessarily demand a different environment. Unlike serial publications in the domain of fiction, each part will aim at being complete in itself, in the light of its predecessors, for, in the world as at present constituted, it is a rash, if not a provocative, prophecy to announce that any form of activity will be "continued in our next".

I. Systematic Discussion of the genera *Pygaster*, Agassiz, and *Plesiechinus*, Pomel.

1. Introduction.

The conservatism of the Holectypoida, and in particular of the family Pygasteridæ, while rendering the order a favourable group for phylogenetic study, has been a condition contributory to the utmost systematic confusion. It is to be hoped that there are few orders, so small numerically, whose nomenclature is so involved. To a considerable extent the lamentable taxonomic chaos into which the family has fallen, is due to the two common causes of such a state—inadequate description and erroneous identification of species. Other preventable errors have been numerous, but the root of the trouble is buried in the nature of the family itself. Where evolution is almost stagnant, even generic differences will be slow to appear and indistinct in their early stages; specific characters must be still less clearly defined. In default of any striking features by which to diagnose their types, authors have tended to use as specific criteria such variations of form and detail as would be considered unworthy of more than passing reference in more plastic groups. Finally, when there is added to these difficulties the fact that the genotype of *Pygaster* was subsequently degraded to the position of a synonym, and, when revived, imagined to be a form from a totally different horizon, and belonging to a different section of the family, it will be realized that a systematic revision of that genus is a necessary preliminary to any morphological study of its species.

Unfortunately, the two specific names most familiar to British geologists ("*P. semisulcatus*" and "*P. umbrella*") have to be changed. The impersistence of palæontological nomenclature is a source of considerable difficulty to students and teachers, and of ironical amusement to those less intimately affected. The trouble is aggravated by the fact that abundant and early known species reflect most frequently the flickering light of systematic research. Realizing to the full, by personal experience, the gravity of the confusion caused by such changes, I sought long for a loophole through which the current nomenclature could be thrust. But I am convinced that there is none. A shelving of the matter would only postpone the inevitable rectification, and meanwhile involve the whole subject in greater confusion. If the truth will out, then the sooner the better. With the hope of making this unpleasant change final, I have studied and catalogued upwards of 400 papers that had any bearing, however remote, upon the question. As a result I feel confident that no further alteration, depending upon past literature, will be necessary for any who are willing to follow logically and impartially the laws of nomenclature. No excuse is necessary for the amount of space devoted to this least inspiring aspect of the forms to be discussed, since it can there be seen on what evidence the changes are made; and, if any error or omission occurs, speedy correction can be made.

In respect of the generic classification, no essential modifications are introduced. The scheme adopted by me in 1912 (Proc. Zool. Soc.) seems adequate, as far as concerns the family under review. Apart from alterations in nomenclature, to be discussed later, the chief difference in the present arrangement lies in the elevation of the subdivisions, previously suggested as subgenera of *Pygaster*, *s. lat.*, to the rank of independent genera. The reasons for this change cannot be considered here, but will, I believe, obtain justification when their morphological basis is published.

2. The Type of *Pygaster*, Agass.

The genus *Pygaster* was founded by Agassiz in 1836 (*Prodrôme*) to include two species, *Clypeus semisulcatus*, Phillips, and *Nucleolites depressus*, Münster in Goldfuss. The species were mentioned in this order, and, since the former conforms more closely to the brief diagnosis first given, it must be regarded as the genotype. *Nucleolites depressus* is an entirely different form. In 1839 Agassiz, giving the first full description of the genus, accompanied by that of several species, omitted to include either of the forms for which he had originally proposed it. He stated (*Ech. Suisse*, p. 80) that he knew of six species, three from the Cretaceous and three from the Jurassic. Of the Cretaceous types, *Macropygus truncatus* was probably one, and *Anorthopygus orbicularis* may have been another, but a third was never described by him. Four Jurassic species are recognized in the work, in spite of the reference to three only in the generic discussion; they are *P. laganoides*, *P. patelliformis*, *P. tenuis*, and *P. umbrella*. There is thus no reference to the genotype. When the name *semisulcatus* reappears (Desor, *Mon. Gal.*, 1842) it is found as a synonym of "*P. umbrella*". The dire confusion that subsequently befell the nomenclature of two important species is dealt with in the next section.

For the present purpose it is sufficient to note that there exists such a species as *Pygaster semisulcatus*, figured by Phillips (*Geol. Yorks.*) under the name of *Clypeus*, though not described by him; and that it was originally found, and may yet be collected, in the Coralline Oolite of Malton. This form must, then, represent the type of *Pygaster*, the Inferior Oolite species to which the name has been most frequently applied, being here regarded as not even congeneric. *Pygaster*, with its restored genotype, will include three of the four species described by Agassiz in 1839—*P. patelliformis*, *P. tenuis*, and "*P. umbrella*"—and so may be taken as expressing most adequately the original meaning of its author. It will absorb the subgenus *Megapygus* proposed by me in 1912, that name having been given in ignorance of the real meaning of the term "*P. semisulcatus*".

3. The Name *Pygaster semisulcatus*, Phillips, sp.

The name *Clypeus semisulcatus* was given in 1829 by Phillips (*Geol. Yorks.*) to a species from the Coralline Oolite of "Malton, Scarborough, and Wiltshire". No description was published, but a recognizable figure (reduced in size and obliquely adapical in view) was printed. Forms conforming in character to that figured may still be found at the first locality mentioned, and, since no other echinoids at all similar occur there, no doubt can exist as to the species intended. The actual specimen used for the drawing cannot be traced, and has probably suffered the fate of many of Phillips' types. The absence of a holotype is particularly unfortunate, since much confusion surrounds the application of the name. As will be seen later, it is necessary to select a specimen as a lectotype.

In 1836 Agassiz included *C. semisulcatus* in his new genus of *Pygaster*, of which it must be regarded as the type. He would appear to have been guided solely by the figure published by Phillips. In 1839 Agassiz refers presumably to this species (*Ech. Suisse*, p. 79). Apart from a casual reference, however, *P. semisulcatus* does not appear in the work, and, to judge from the evidence available, Agassiz must have considered it synonymous with one of the species there diagnosed, probably with *P. umbrella*. Desor, in 1842, was more explicit (*Mon. Gal.*, p. 77), inserting the name in the list of synonyms of *P. umbrella*. On p. 76 he says that *C. semisulcatus* "pourrait fort bien n'être autre chose qu'un jeune de notre *P. umbrella*". Since Phillips' figure was, according to Forbes, two-thirds the size of its original, the dimensions of the Yorkshire specimen will have been not far short of those of the Swiss *P. umbrella*, their identity being thus rendered more possible. It is necessary, then, in view of the conceivable identity of *Clypeus semisulcatus*, Phill., and *Pygaster umbrella*, Agass., 1839, to discuss briefly the justification for the former name. Obviously, if the two names apply to the same species, that of Agassiz, supposed to be derived from Lamarck (1816) and perhaps from Leske (1778), would have priority.

There can be no doubt that the figures of *Galerites umbrella* in the *Encycl. méthod.* (pl. cxlii, figs. 7, 8) represent a species of *Clypeus*, presumably *C. sinuatus*, Leske. The descriptions given by Lamarck, Deslongchamps, and de Blainville all agree more closely with the generic characters of a *Clypeus* than of a *Pygaster*. Agassiz (1839) hesitated to include *C. sinuatus*, Leske, in his list of synonyms of *P. umbrella*, although he inserts the *Nucleolites umbrella* of Desmoulins, which included Leske's species. Desor (1842), following on and amplifying the descriptions of Agassiz (probably with his collaboration), definitely placed *Clypeus sinuatus* among the synonyms of *P. umbrella*, and, to complete his identification, inserted a reference to the description and figure given by Klein (1734) as *C. plotii*. In 1847 (*Cat. Rais.*) both authors jointly recognized the error of including *Clypeus sinuatus* in the genus *Pygaster*, and deleted all the previous synonyms of *P. umbrella* except the reference to Lamarck. They gave to the original *P. umbrella* the new name of *P. dilatatus*, and, to add to the confusion, briefly diagnosed a new species under the old name; surely a most disastrous way of rectifying a mistake! With this complication, however, we are not immediately concerned. The question of the relation between the names *semisulcatus* and *umbrella* (supposing them to refer to the same species) turns on the description of *Galerites umbrella* by Lamarck. The use of the generic term *Galerites* affords no guidance, for Lamarck applied it to many forms which cannot be classed as Holectypoida. He gives a reference to *Clypeus sinuatus*, Leske, and to the figure in the *Encyclopédie* (Lamarck, *An. s. vert.*, iii, p. 23), and describes his *Galerites umbrella* as "sulcis ambulacrorum angustis biporosis substriatis". As Salter remarked (Mem. Geol. Surv., Dec. V, 1856), the last word seems to imply a petaloid or subpetaloid ambulacral structure that is incompatible with the characters of a *Pygaster*. There seems, therefore, little doubt that Lamarck's species was a *Clypeus* or a *Nucleolites*, and was thus in no way to be identified with the *Pygaster umbrella* of Agassiz in 1839, nor with the later species given that name in 1847.

Since all the references given by Agassiz in 1839 for *P. umbrella* seem to have no real connection with that species, it follows that the name *P. umbrella*, Agassiz, 1839 (*excl. syn.*), can be applied only to the form figured by him—known at that time by a unique and partly decorticated specimen, from the "Portlandien du Jura Soleurois". The name itself, denuded of its list of synonyms, is valid enough, but it dates back no further than 1839. Hence, if *Clypeus semisulcatus*, Phill., and *Pygaster umbrella*, Agass., are synonymous, the former name has ten years priority, and can in any case be maintained.

Morris (*Cat. Brit. Foss.*, 1843), and later Salter (loc. cit.), recognized the true nature of Lamarck's *Galerites umbrella*, and followed Desor in his identification of the two species, but naturally regarded *P. umbrella* as a synonym of *P. semisulcatus*. Unfortunately Salter's *P. semisulcatus* was quite a different species from Phillips' original one, so that the way to further confusion was opened by his otherwise logical action.

It seems doubtful whether any reliable specific criteria can be recognized in the original specimen of *P. umbrella*, Agass., 1839. The bad preservation of the type makes reference of other specimens to it dangerous. If the species usually called *P. dilatatus* (the second name given by Agassiz to his former *P. umbrella*) is really that of 1839, then it may be stated with confidence that it is not synonymous with *P. semisulcatus*. I have shown above that, whatever might be the result of such an inquiry, the name *semisulcatus* is either independent of, or must supersede, that of *umbrella*.

Having established the legitimacy of the specific name *Pygaster semisulcatus*, we can turn to the history of its use by British authors.

For sixteen years after the publication of *Clypeus semisulcatus*, that species was the only *Pygaster* recognized by name in Britain. Indications that another species had been collected are to be found in Morris (loc. cit., 1843), where *P. semisulcatus* is recorded from the "Great Oolite" (really Inferior Oolite) of Gristhorpe, Yorks, in addition to its original Corallian localities. It seems, however, that very great confusion existed as to the generic character of the Corallian Pygasters. Parkinson (*Org. Rem.*) referred to *Clypeus sinuatus* specimens from the Coral Rag of Berkshire and Oxfordshire, which were in all probability species of *Pygaster*. Conybeare and Phillips (*Geol. Eng. and Wales*) followed him in regarding *C. sinuatus* as a characteristic fossil of the Inferior, Great, and Coralline Oolites; and, as late as 1850, Mantell, in republishing some of Parkinson's drawings, emphasized the frequent occurrence of *C. sinuatus* in the Corallian. It is true that species of *Clypeus* and *Pygurus* have been found in the British Corallian, but they are extremely rare, so that it is most improbable that these references actually apply to them.

In 1844 Buckman (Murchison's *Geology of Cheltenham*), recognizing the difference between the "*Clypeus*" of the Inferior Oolite of the Cotteswolds and that of the Corallian, distinguished the former species as *C. ornatus*, and in 1848 M'Coy (*Ann. Mag. Nat. Hist.*) gave the name *Pygaster brevifrons* to a form from the Inferior Oolite of Dundry Hill. The latter author followed Agassiz and Desor in their identification of *Clypeus semisulcatus* with *Pygaster umbrella* (M'Coy, loc. cit., p. 414), and recorded a specimen from the Coralline Oolite of Malton under the latter name (id., p. 420).

The first published reference of the name *P. semisulcatus* to the Inferior Oolite species seems to have been that by Brodie (Q.J.G.S.) in 1851. His identification of the Cotteswold forms with the Yorkshire species was probably influenced by Wright, who, in the following year (*Ann. Mag. Nat. Hist.*), united under the one specific name forms from the Pea Grit, Great Oolite, and Coralline Oolite. Forbes in 1854 (*Morris' Cat.*, 2nd ed.) endorsed the identification of these diverse species, still citing *P. umbrella*, Agass., 1839, as a synonym. Two years later (Mem. Geol. Surv., Dec. V) he repeated the error, identifying actual specimens from the Inferior Oolite of Gloucestershire and the Coral Rag of Faringdon under the name *P. semisulcatus*.

It is important to realize the prevalence of this belief in the occurrence of the same species of *Pygaster* in the Corallian and Inferior Oolite, because Phillips, when asked by Forbes to supply a typical specimen of his *C. semisulcatus*, sent a specimen from the Inferior Oolite of Whitwell. The actual holotype was lost by this time, so that this specimen came to be regarded as the true representative of the species, in defiance of the references of 1829.

The year 1856 was a critical one in the history of the specific name. Both Wright and Salter then came to recognize the essential difference between the lower and middle Oolitic species, and, owing to Phillips' error, applied the name *semisulcatus* to the Inferior Oolite form. The degree of confidence, coupled with lack of logic, with which this wrong determination was made, can be gauged by the following quotation from Wright (Pal. Soc., Ool. Ech.): "It was an error in the determination of the species, which led Professor Phillips to state that *Pygaster semisulcatus* was found in the Coralline Oolite of Yorkshire, that form never yet having been found in Yorkshire out of the Whitwell beds—Inf. or Great Oolite." It is difficult to understand how an author could be in error in the determination of a *new* species at the time when he first recorded and figured it, especially since the other form with which he is supposed to have confused it had not been recognized at the time; but it was from this paradoxical conclusion of Wright that issued all the confusion in the misapplication of the name. Save for a passing reference by Desor (Synopsis), the name *Pygaster semisulcatus* has not been applied to a Corallian species since 1856!

Apart from the fact that the original reference to *Clypeus semisulcatus* included solely Corallian localities, the figure given, though imperfect in some respects, shows quite clearly the pyriform shape of the periproct—a feature utterly unlike anything found in any Inferior Oolite species. The climax of the unnecessary confusion introduced in 1851 is found in the third edition of Phillips' work (by Etheridge) in 1875. Here the original figure of 1829 is reprinted, and referred to as *Pygaster umbrella*, Agassiz, while the name *semisulcatus* is transferred to the Whitwell forms on the same page. Such a glaring absurdity cannot be allowed to remain.

As stated above, the type of *Clypeus semisulcatus* was lost before 1856, and has not been seen since. Even if it is still in existence (or if any one specimen was actually selected in 1829), it would be impossible to identify it with certainty. No description or measurement was given, nor could the latter be deduced from the drawing. This is said to be two-thirds of the natural size, but, since the specimen is viewed obliquely, neither diameter nor height could be accurately calculated. It becomes necessary, therefore, to select a specimen to replace the missing holotype, so that future references may rest on a more secure foundation than hitherto. Malton was the first mentioned locality, and from the quarries near that town specimens are still obtainable. A very beautiful specimen from this locality is in the British Museum (No. E 1645). It is the one used by Wright for his drawings of the adoral surface and apical system of "*P. umbrella*" (Pal. Soc., *Ool. Ech.*, pl. xx, figs. 2*b*, *e*), and I hereby select it as the lectotype (also a topotype) of *Pygaster semisulcatus*, Phill., sp. This specimen thereby becomes the type of the genus *Pygaster*, Agass.

For the species from the Inferior Oolite, so long miscalled *P. semisulcatus*, the name *Clypeus ornatus*, Buckman, 1844, is available. This has clear priority over the only other specific name applied to the species during the period of its recognition (*P. brevifrons*, M'Coy, 1848). This form must in future be known as *Plesiechinus ornatus*, Buckman, sp.

4. The type of *Plesiechinus*, Pomel.

This genus was proposed in 1883 by Pomel, to include those species of *Pygaster* whose characters show the nearest approach to those of the Regular Echinoids. Three of such species were mentioned by him: *P.* "*megastoma*", Wright, *P. semisulcatus*, "Wright," and *P. speciosus*, "Quenst." One of these three must be the genotype. *P. speciosus*, "Quenst.," the last mentioned, is by no means well known (supposing it to be the *Nucleolites speciosus* of Goldfuss), and may not belong to the Pygasteridæ. The name *P. semisulcatus*, "Wright," refers to the most abundant and best-known species of the three, but unfortunately it is not the true *P. semisulcatus* (Phill.). It would be confusing to implicate the generic name in the systematic turmoil surrounding the species. The choice will fall, therefore, upon *P.* "*megastoma*", Wright. In spite of its author's doubts as to its separation from his *P. semisulcatus*, the two species are quite distinct, in both characters and horizon. The appropriateness of the choice is enhanced by the fact that the apical system, on the structure of which Pomel based the genus, is best known in this one of the three species.

Some discrepancy in the spelling of the name of the genotype has occurred, owing to the printing of no fewer than three different versions by Wright at the time of its first appearance. Of these, *macrostomus* (Wright, Pal. Soc., *Ool. Ech.*, p. 424), although the first in order, may be dismissed as barbarous and probably accidental. There is little to choose between the two other renderings, *macrostoma* and *megastoma*, in respect of their etymology, but since the former accompanies the description of the species, and is several times repeated (loc. cit., pp. 463, 464), it has a technical advantage over the latter, which is employed only on the legend to the plate. Moreover, the name *macrostoma* has been adopted by authors generally (with the exception of Pomel), and so may be stereotyped as the correct designation of the species.

The genus *Plesiechinus* was either rejected or ignored by writers from the time of its publication until 1912, when I provisionally adopted it (Geol. Mag.) on grounds similar to those that caused its proposal. Later in the same year (Proc. Zool. Soc.) I rejected the name on systematic considerations, but retained the division under the name of *Pygaster* s.str. This was due to a misconception of the meaning of the name *P. semisulcatus* (the genotype of *Pygaster*, Agass.). Having recognized that the *P. semisulcatus* of authors later than 1850 is entirely different from that of previous writers, and belongs to a different genus, I have been compelled to retain the generic name *Pygaster* for the former type, so that the name *Plesiechinus* can be revived for the latter.

Some further apology for the reinstatement of a genus rejected by so many authorities seems necessary. The original diagnosis given by Pomel is as follows: "Ce sont des *Pygaster* dont l'apex est formé de quatre génitales peu inégales, disposées en demi-cercle, ainsi que les ocellaires postérieures, et formant le cadre supérieur du périprocte, qui est oblong et très vaste." The only criticism that can be made concerns the final words. The periproct in *P. macrostoma* is certainly large, but not so extensive, in proportion, as it is in many species of the true *Pygaster*. The reference to its shape, and the description of the apical system, hold good. As will be found in the detailed analyses that will appear in later papers of this series, there are many other features in which the species of *Plesiechinus* resemble one another and differ from those of the other Pygasterinæ, but I feel convinced that, in this case, the characters of the apical system are alone sufficient to render the genus valid. The most obvious, as well as most fundamental, difference between Regular and Irregular Echinoids lies in the relation between the periproct and the apical system. Among the Pygasteridæ we have the history of their separation gradually revealed. The first stage is marked by the destruction of the posterior genital plate, and the splaying out of the apical system to give passage to the retreating periproct. Later stages are concerned with the closing in and readjustment of the plates of the system when the aperture has been sufficiently withdrawn. *Plesiechinus*, as here defined, comprises all species that show the first stage of periproct-migration; the other Pygasteridæ include representatives of the later conditions. There are thus sound phylogenetic reasons for the genus, which are rendered the more secure when it is seen that all the species referable to it with certainty are the earliest members of the family. On both morphological and stratigraphical evidence we find in *Plesiechinus* "le type le plus rapproché des globiformes" (Pomel).

Pygaster reynesi, Desor, and *Clypeus ornatus*, Buckman, are two well-defined species of *Plesiechinus*, in addition to the genotype, *P. macrostoma*, Wright.

5. Summary.

The following list includes all the changes rendered immediately necessary as a result of the previous discussion :—

Pygaster, Agass., 1836 (incl. *Megapygus*, Hawkins, 1912).

Type, *Clypeus semisulcatus*, Phill. Corallian (incl. *Pygaster umbrella*, *pars*, auct.) (non *Pygaster semisulcatus*, auct.).

Plesiechinus, Pomel, 1883 (incl. *Pygaster* sens. str., Hawkins, 1912).

Type, *Pygaster macrostoma*, Wright. Bathonian.

Generally speaking, *Pygaster* is a Middle and Upper Oolitic group, and *Plesiechinus* is restricted to the Lias and Lower Oolite.

VI.—The Genotypes of certain Polyzoan Genera.

By W. D. Lang, M.A., F.G.S.

By permission of the Trustees of the British Museum.

In working through the literature of Cretaceous Cribrimorph Polyzoa, it has been found necessary to determine the significance of the genera under which the different Cretaceous species have been placed by various authors, and, consequently, the genotypes of these genera. In several cases where a genus has been founded upon more than one species, apparently no subsequent author has definitely chosen a genolectotype from the several genosyntypes at his disposal; it has, therefore, seemed desirable to publish a list of certain genera under which various authors have placed Cretaceous Cribrimorph forms, namely those of which the genotype is or has been in doubt. It is hoped thus to simplify the work of future authors and to reduce to less confusion the somewhat chaotic use of certain names.

I wish to record my obligations to my colleague, Dr. S. F. Harmer, for much help and valuable criticism; but it should be noted that the conclusions arrived at do not always coincide with his opinions.

Antropora, Lang, 1916, pp. 86, 91; genotype, *A. cavernosa* Lang, 1916, pp. 91, 92; *Antropora* is preoccupied by Norman, 1903 [2], p. 87; genotype, *Membranipora granulifera*, Hincks, 1880 [2], p. 72, pl. ix, fig. 4; Recent, Madeira. *Cœlopora* is proposed for *Antropora* Lang, non Norman. I am obliged to Dr. S. F. Harmer for pointing out this error of mine, as well as another in the case of *Corymbopora*.

Barroisina, Jullien, 1886, p. 605; genotype, *Repteschariporа elegantula* von Hagenow sp., Beissel, 1865, pp. 60, 11, 90, pl. vii, fig. 82; non *Cellepora* (*Escharina*) *elegantula*, Hag.; von Hagenow, 1851, p. 90, pl. x, fig. 13.

Cellepora, Linnæus, 1767, p. 1285; genosyntypes, six Recent species, of which *Cellepora pumicosa* Linnæus is taken by Hincks (1880 [1], p. 398) as the genolectotype.

Cœlopora, n.gen.; genotype, *Antropora cavernosa* Lang, 1916, pp. 91 and 92; see *Antropora*.

Corymbopora, Lang, 1916, pp. 382, 385; genotype, *C. religata* Lang, 1916, p. 385. *Corymbopora* is preoccupied by Michelin, 1846, p. 213; genotype *C. menardi* Michelin, 1846, p. 213, pl. liii, fig. 10; see *Corymboporella*.

Corymboporella, n.gen.; genotype, *Corymbopora religata* Lang, 1916, p. 385.

Cribrilina, Gray, 1848, p. 116; genotype, *Lepralia punctata*, Hassall, 1841, p. 368, pl. ix, fig. 7; *Cribrilina* is so frequently used for Cretaceous Cribrimorphs, without further explanation, that it is as well to emphasize the genotype.

Dermatopora, von Hagenow, 1851, pp. 87, 98; genosyntypes, *Cellepora* (*Dermatopora*) *monilifera* von Hagenow, 1851, p. 98, pl. xi, fig. 1; *Cellepora lyra* von Hagenow, 1839, p. 269, pl. iv, fig. 8; *Cellepora ornata*, Goldfuss, 1826, pp. 26, 248, pl. ix, fig. 1; *Cellepora* (*Dermatopora*) *faujasi* von Hagenow, 1851, p. 99, pl. x, fig. 19; genolectotype (here chosen), *Cellepora* (*Dermatopora*) *monilifera* von Hagenow, 1851, p. 98, pl. xi, fig. 1.

DISCOPORA, Lamarck, 1816, p. 164; genosyntypes, nine Recent species, of which Gray (1848, p. 126) has chosen *Cellepora verrucosa* Esper, 1790, p. 239, pl. ii, figs. 1 and 2 (= *Tubipora verrucosa* Linnæus, 1758, p. 789) as genolectotype. At the same time, Gray explains that the *Cellepora verrucosa* of Esper is not the *C. verrucosa* of Lamarck. Until the identity of *Cellepora verrucosa* is determined, the interpretation of *Discopora* must remain uncertain.

DISTANSESCHARELLA, d'Orbigny, 1853, p. 463; genosyntypes, *Cellepora familiaris* von Hagenow, 1839, p. 274; *Escharina inflata*, Römer, 1840, p. 14, pl. v, fig. 5; *Escharina radiata* Reuss, 1846, p. 68, pl. xv, fig. 19; genolectotype, *Cellepora familiaris* von Hagenow, 1839, p. 274; see Lang, 1916, p. 387.

ESCHARA, Linnæus, 1758, p. 804; genosyntypes, *E. foliacea* Linnæus, 1758, p. 804; *E. fistulosa* Linnæus, 1758, p. 804; *E. fragilis* Linnæus, 1758, p. 805; *E. divaricata* Linnæus, 1758, p. 805; *E. verticillata* Linnæus, 1758, p. 805; genolectotype, *E. foliacea*, Linnæus, 1758, p. 804, implicitly chosen by Linnæus (1761, p. 539), who, in establishing the name *Flustra* to supplant the name *Eschara*—"nomen *Escharæ* in *Flustram* transmutavi, cum prius Morbi homonymon"—mentions three species of *Flustra*, of which the first two are *F. foliacea* and *F. fistulosa*, and the other does not occur among the genosyntypes of *Eschara*; again, in 1767, pp. 1300, 1301, he gives six species of *Flustra*, of which the first, *F. foliacea*, is the only genosyntype of *Eschara*; it seems clear then that *E. foliacea* was in Linnæus' mind as typical when *Eschara* was founded; besides, *F. foliacea* is commonly recognized as the genolectotype of *Flustra*. See also under *Flustra*.

ESCHARELLA, Gray, 1848, p. 125; genosyntypes, *Berenicea immersa* Fleming, 1828, p. 533; *Lepralia violacea* Johnston, 1847, p. 325, pl. lvii, fig. 9; *Lepralia variolosa* Johnston, 1838, p. 278, pl. xxxiv, fig. 4; all Recent; genolectotype, *Berenicea immersa* Fleming, 1828, p. 533, selected by Norman, 1903 [2], p. 117.

ESCHARINA, Edwards in Lamarck, 1836, pp. 218, 230; genotype, *E. vulgaris* Moll, 1803, p. 55.

ESCHARIPORA, d'Orbigny, 1852, p. 220; genosyntypes, seventeen Senonian species, of which *E. inornata* d'Orbigny, 1851, pl. 686, figs. 17–19, 1852, p. 230, is here chosen as the genolectotype.

ESCHAROIDES, Edwards in Lamarck, 1836, pp. 218, 259; genosyntypes, eleven Recent and eight fossil species, of which Verrill, 1879, p. 149, selected *Cellepora coccinea* Abildgaard, 1806, p. 30, pl. cxlvi, figs. 1 and 2, as genolectotype.

FLUSTRA, Linnæus, 1761, p. 539; genosyntypes, *F. foliacea*, Linnæus, 1761, p. 539 (= *Eschara foliacea* Linnæus, 1758, p. 804); *F. fistulosa* Linnæus, 1761, p. 539 (= *Eschara fistulosa* Linnæus, 1758, p. 804); *F. pilosa* Linnæus, 1761, p. 539. In establishing the name *Flustra*, however, Linnæus states positively that he is replacing the name *Eschara*—"nomen *Escharæ* in *Flustram* transmutavi"—by *Flustra*. Therefore *Eschara* and *Flustra* are by definition, synonyms, and, since Linnæus himself had no power to supplant one of his own names, *Eschara* must stand and *Flustra* fall. Since, however, the name *Flustra* is invariably used for *F. foliacea*, the genolectotype of this genus and of *Eschara* (see under *Eschara*), while *Eschara* is used variously, it would be desirable, if possible, to standardise the name *Flustra* and delete *Eschara* from zoological nomenclature.

HIPPOTHOIDA, Vine, 1893, p. 316; *Hippothoida brevis*, Reuss, is written for *Hippothoa brevis* Reuss; it is clear that Vine did not intend thereby to found a new genus, but that *Hippothoida* is a *lapsus* for *Hippothoa*.

LAGODIOPSIS, Marsson, 1887, p. 99; genotype, *Multescharipora francqana* d'Orbigny, 1852, pl. 734, figs. 6–8, 1853, p. 497; this species is generally considered congeneric with *Murinopsia* Jullien, 1886, p. 608, with the genotype *Semiescharipora galeata* Beissel, 1865, p. 55, pl. vi figs. 70–75, pl. vii, fig. 76; in this connection it may be observed that Marsson mentions a second species of *Lagodiopsis*, namely *Cellepora pinguis* von Hagenow, 1851, p. 88, pl. x, fig. 15, a form probably congeneric with *Cribrilina triceps* Marsson, 1887, p. 98, pl. x, fig. 12, and therefore a *Tricephalopora*; but it seems that Marsson meant to found *Lagodiopsis* upon *Multescharipora francqana* d'Orbigny and that this species therefore must be regarded as the genotype.

LEKYTHOGLENA, Marsson, 1887, p. 90; genosyntypes, *L. ampullacea* Marsson, 1887, p. 91, pl. ix, fig. 7; *L. effigurata* Marsson, 1887, p. 91, pl. ix, fig. 8; genolectotype, *L. ampullacea*, Marsson, 1887, p. 91, pl. ix, fig. 7, see Lang, 1916, p. 390.

LEPRALIA, Johnston, 1838, p. 277; genosyntypes, seven Recent species of which Norman, 1903[2], pp. 99, 100, has chosen *L. nitida* Johnson (i.e. *Berenicea nitida* Fleming, 1828, p. 533, non *Cellepora nitida* Fabricius) as the genolectotype. While accepting Norman's solution of a difficult problem, I must admit that it is arguable with equal propriety that *Lepralia* is synonymous with *Escharoides*, Edwards. But, where two solutions are equally tenable, and one has already been deliberately chosen, not to follow this rule would be contrary.

MEMBRANIPORA, Blainville, 1830, p. 411; genosyntypes, six Recent and five fossil species, of which the genolectotype is *Flustra membranacea* Linnæus, 1767, p. 1301; see Norman, 1903[1], p. 585.

MEMBRANIPORELLA, Smitt, 1873, p. 10; genotype, *Lepralia nitida*, auctt., but with reference to Smitt, 1868, pp. 306, 401, on the former page of which it is clear that *Lepralia nitida* Johnston (1838, p. 277, pl. xxxiv, fig. 7) is meant. This species is the genolectotype of *Lepralia*—see under *Lepralia*—of which *Membraniporella* is thus a synonym.

PHRACTOPORA, Lang, 1916, p. 89; genotype, *P. constrata* Lang, 1916, p. 89. *Phractopora* is preoccupied by Hall, 1883, p. 154; genotype, *P. cristata* Hall, 1883, p. 154. I am indebted to Dr. R. S. Bassler for pointing this out to me.

Phractoporella, n.gen.; genotype, *Phractopora constrata* Lang, 1916, p. 89.

Porina, d'Orbigny, 1853, p. 432; genosyntypes, thirteen species; of which two are Recent, seven Tertiary and four Cretaceous; of these, the Recent *Eschara gracilis* Lamarck, 1816, p. 176, is here chosen as the genolectotype.

Prosoporella, Marsson, 1887, p. 100; genotype, *Semiescharipora cornuta* Beissel, 1865, p. 58, pl. vii, figs. 77–81; this species is the genotype of *Decurtaria* Jullien, 1886, p. 606, which thus has the priority over *Prosoporella*.

Reptescharella, d'Orbigny, 1853, p. 464; genosyntypes, six Recent, three Tertiary and twelve Cretaceous species, of which *Eschara lorieri* d'Orbigny, 1851, legend to pl. 604, figs. 11–12 (*Reptescharella lorieri* d'Orbigny, 1853, p. 466) is here chosen as genolectotype.

Reptescharellina, d'Orbigny, 1853, p. 451; genosyntypes, twelve Recent, twelve Tertiary and five Cretaceous species, of which *R. horrida* d'Orbigny, 1852, pl. 715, figs. 7–9, 1853, p. 456, from the Senonian of Tours, Vendôme and Royan, is here chosen as genolectotype.

Reptescharinella, d'Orbigny, 1853, p. 428; genosyntypes, two Recent, one Tertiary and eight Cretaceous species, of which *Cellepora* (*Discopora*) *subgranulata* von Hagenow, 1851, p. 91, pl. xi, fig. 15, from the Maastrichtian of Maastricht, is here chosen as genolectotype.

Reptescharipora, d'Orbigny, 1853, p. 489; genosyntypes, one Recent, two Tertiary and eleven Cretaceous species, of which *R. meudonensis* d'Orbigny, 1852, pl. 719, figs. 17–19, 1853, p. 491, is here chosen as genolectotype.

Reptocelleporaria, d'Orbigny, 1852[2], p. 679 [name only], 1853, p. 421; genosyntypes, three Recent, ten Tertiary and two Cretaceous species, of which *R. cretacea* d'Orbigny, 1852, pl. 713, figs. 17–18, 1853, p. 423, from the Senonian of Meudon, is here chosen as genolectotype.

Reptoporella, d'Orbigny, 1853, p. 474; genotype, *R. regularis* d'Orbigny, 1852, pl. 717, figs. 6–7, 1853, p. 475; this species is possibly congeneric with *Leptocheilopora tenuilabrosa* Lang, 1916, pp. 396–7, and, if so, the genus *Leptocheilopora* Lang, 1916, p. 396, must give place to *Reptoporella*.

Rhiniopora, Lang, 1916, pp. 93, 96; genosyntypes, ten Cretaceous species, of which *R. aspera* Lang, 1916, pp. 96, 97, is here chosen as genolectotype.

Semieschara, d'Orbigny, 1852, p. 364; genosyntypes, four Recent, two Tertiary and nineteen Cretaceous species, of which *S. flabellata* d'Orbigny, 1852, p. 367, pl. 708, figs. 1–4, is here chosen as genolectotype.

Semiescharipora, d'Orbigny, 1853, p. 479; genosyntypes, one Tertiary and thirteen Cretaceous species, of which *S. complanata* d'Orbigny, 1852, pl. 718, figs. 17–20, 1853, p. 484, is here chosen as the genolectotype.

Steginopora, d'Orbigny, 1853, p. 499; genosyntypes, *S. irregularis* d'Orbigny, 1852, pl. 720, figs. 16–19, 1853, p. 500; *S. ornata* d'Orbigny, 1852, pl. 721, figs. 1–4, 1853, p. 501; *S. aculeata* d'Orbigny, 1852, pl. 721, figs. 5–8, 1853, p. 502; *S. pulchella* d'Orbigny, 1852, pl. 721, figs. 9–12, 1853, p. 503; genolectotype, *S. ornata* d'Orbigny, 1852, pl. 721, figs. 1–4, 1853, p. 501; see Lang, 1916, p. 100.

THORACOPHORA, Jullien, 1886, p. 610; genotype, *Escharina horrida* d'Orbigny, 1850, p. 264, which is the genotype of *Disteginopora*; *Thoracophora* Jullien is, therefore, a synonym of *Disteginopora* d'Orbigny, 1852, p. 235. N.B. Dr. Harmer has pointed out to me that in the Zoological Record, vol. xxiii, 'Polyzoa,' p. 12, the recorder—Hoyle—states that *Thoracophora* is preoccupied.

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REVIEWS.

I.—IRREGULARITIES IN THE POST-GLACIAL UPLIFT OF NORWAY.

BY measuring the present heights of old sea-beaches the Scandinavian geologists have been able to work out the salient features of the tilt their country has acquired during its rise in Post-Glacial times. To demonstrate the amount and character of the uplift since any particular period, it is first necessary to distinguish the beach formed at that period, which is itself often a matter of considerable difficulty owing to the presence of other beaches, and then to measure the various levels at which it now occurs. These determinations are marked on the map, and from them lines—the isobases—are drawn such that for any points on one line the present height of the beach is the same, the lines being drawn for convenient and constant differences of level. Thus the character and degree of uplift are seen at a glance, the isobases lying closer together where the tilt is greater and farther apart where it is less. These maps are usually drawn on a small scale, and the isobases appear as smooth parallel lines with a fairly constant distance between, indicating that the country has yielded to the forces of upheaval as one homogeneous mass.

Recently, by determining the heights of old beaches with great care and plotting on a large scale map, Holmsen has found that the isobases in some districts swing right out of their normal course, proving minute but unmistakable inequalities of uplift.[1] The beaches of former ice-dammed inland lakes are better adapted for this accurate work than those marking ancient sea-shores in the coastal regions, because they are in a more complete state of preservation. This is to be expected when it is remembered that the sea-level sank little by little, so that there is not only a risk of confusing the various coast beaches, but they have often been mutilated and sometimes obliterated by the waves of the gradually falling sea surface. As the glacial lakes were suddenly drained, no such force has operated to mar their beaches, the levels of which can be determined with great accuracy.

[1] "Om Strandlinjernes Fald omkring Gabbroomraader": Gunnar Holmsen, Norsk Geologisk Tidsskrift, Bd. iv, H. i, pp. 7–20, 1916.

The northern part of the østerdal is the site of an old ice-dammed lake and two beaches are present, one being about 55 m. above the other. Holmsen gives a map of the district with the isobases of the lower beach drawn for every 5 m. difference in level. A general tilt away from the ice-shed, which lay to the south-east, is revealed. The isobases run regularly across the mountainous country of granite and altered sedimentaries, but are turned aside by a gabbro mountain. The plane of the former lake-level dips, on the north-west side of the gabbro, at a rate of 0·85 to 1·63 metres per kilometre, being greater than the average gradient of the district, which is 0·70 m. per km., whilst on the opposite side the normal north-west dip is lessened and even reversed. This can be explained by postulating a greater uplift of the gabbro than that of the whole district, and this view receives additional support from a consideration of the vertical relations of the two beaches, which are not quite parallel to each other. Compared with the lower beach, the upper one exhibits higher levels the nearer it is situated to the gabbro mountain. Near the gabbro the upper beach is 57·9 m. above the lower, but only 54·5 m. some distance away, showing that the extra upheaval of the gabbro was in progress before the lower and younger beach was formed, as well as afterwards.

Although for the reasons pointed out above the evidence is not so detailed, the present heights of two raised sea-beaches in North Norway, between Tromsø and Hammerfest, mapped by Helland, show the great masses of basic eruptive rocks to be standing higher relatively to the surrounding country than they did formerly. It is known that slight irregularities of uplift can sometimes be referred to irregularities in surface relief, but this is not the determining factor in the cases discussed by Holmsen, where, significantly, the specially raised districts are all built up of heavy basic eruptive rocks. The phenomena would seem to be connected with the greater density of the masses affected, although it is not at all clear how this has operated. One cannot help admiring the precision of this work, whereby such minute variations in the uplift of the land have been discovered and measured.

L. Hawkes.

II.—Notes on the Geology of Chitral, Gilgit, and the Pamirs. By H. H. Hayden, C.I.E., F.R.S., Director Geological Survey of India. Rec. Geol. Surv. India, vol. xlv, pt. iv, pp. 271–335, 1915.

In this part is contained an interesting account of a preliminary geological reconnaisance through Chitral, the Gilgit district, and the Pamirs. In the outer mountains of Dir and Swat there is a belt of igneous and metamorphic rocks, which is probably the equivalent of the igneous and metamorphic series which occurs below Jelalabad on the Kabul River. Between Dir and Chitral granite is found, but north of the Laorai Pass this gives place to a series of sedimentary rocks, which comprise members at least as old as the Devonian and as young as the Cretaceous. This series extends across from Chitral to the districts of Yasin and Hunza. To the north of this series is found a belt of slates, which extends from the Wakham (Nicholas) range to the Taghdumbash Pamir in Chinese Turkestan, and this is followed further north by a calcareous series known as the Pamir Limestone. This is the most prominent rock of the Russian Pamirs, and includes rocks of Triassic and Jurassic age. North of the Pamir Limestone comes a group of slates, probably identical with those of Wakham, but associated with shales and limestone containing Upper Devonian fossils. Beyond this belt, in the valley of the Kizil-su, there is a typical development of the Ferghana series. The strike of all these rocks, both in Chitral and the Pamirs, follows the general direction of the ranges. In Chitral it changes from S.W.–N.E. in Western Chitral to W.–E. in the Yasin district, and no doubt turns down to the south farther east. In the Pamirs the strike in the central parallel ranges is W.–E., and this swings round to the S.W. at the west end and to the S.E. at the east end, following the general lines of the great bay in the Himalayan folds, which contains the North-West Provinces of India. These observations show that the Chitral Mountains and the Pamirs are true tectonic features.

Up to the present the Pamirs have always been represented on maps as being bounded on the east by two parallel ranges running north and south, which were assumed by Suess and Fütterer to be true tectonic features, and to indicate a great irregularity in the trend of the chief structural lines of this part of Asia. This, however, is not the case. In both these ranges the strike is fairly constantly W.–E., at right angles to the trend of the range, and only occasionally turns to the N.W.–S.E. The western or Sarikol range may then be regarded as "the eroded scarp of the Pamir plateau", while the eastern or Kashgar range probably owes its origin to the elevation and induration of the strata round the granite masses which form the peaks of Kungur and Mustagh-ata. The strike probably changes round these granites, but not more than is usually the case in the neighbourhood of large intrusions; so that the range is only partly tectonic, and offers no evidence in favour of the theories of Suess and Fütterer.

W. H. W.

III.—Platiniferous Deposits of Spain and Russia. Etude comparée des Gites Platinefère de la Sierra de Ronda et de l'Oural. Par Louis Duparc et Augustin Grosset. Mém. Soc. Phys. Hist. Nat. Genève, vol. xxxviii, pp. 253–290, 1916, avec 7 figures, 1 carte, et 4 planches.

Peridotites and serpentines occur on an extensive scale on the southern slopes of the Sierra de Ronda, between Malaga and Estopona, and M. Orueta, who has recently mapped the district on a scale of 1 : 100,000, impressed by the resemblance of the rocks to those which are now recognized as the source of platinum in the Urals, examined the alluvia of several rivers draining the district and found platinum in them.[1]

[1] In a note published in the Comptes Rendus Acad. Sci. Paris, tom. 162, p. 45, 1916, M. Orueta states that 50 "sondages" in the alluvial deposits yielded on the average 3 grams per cubic metre, with a maximum of 28 grams.

In consequence of this discovery the two authors of the memoir under review, one of whom, M. Duparc, has made a special study of the Russian deposits, visited the Spanish locality in order to compare the modes of occurrence in the two countries. Their work was greatly facilitated by M. Orueta, who supplied them with a copy of his unpublished map.

The memoir begins with a description of the topography, geology, and petrography of that portion of the Sierra de Ronda in which the platiniferous deposits occur. The principal constituents of the ultrabasic rocks are spinels, rhombic and monoclinic pyroxenes, and olivine. These constituents are mixed in varying proportions. The most common variety is composed of brown spinel, olivine, and a rhombic pyroxene (hartzburgite). Next to this comes a variety containing a monoclinic pyroxene in addition to the above-mentioned constituents (lherzolite). A third type corresponds to dunite. But all these varieties shade into each other and all are liable to serpentinization. The authors compare the structure of those areas in which dunite is found to a sponge; dunite filling the hollows and the other varieties forming the network. They consider that the peridotites were intruded into the surrounding gneissose and more or less metamorphosed sedimentary rocks after the Cambrian period and before the formation of a conglomerate, which is either of Permian or Triassic age; but no satisfactory evidence of the reference of any of the surrounding sedimentary rocks to the Cambrian period is given.

M. Orueta supplied the authors with a few small grains of platinum. Two varieties were noticed. One shows under the microscope polygonal depressions which are precisely similar to those observed on grains derived from pyroxenic rocks in the Urals. They possess a yellowish bronzy lustre and have generally been much rounded. The other variety, also rounded, appears absolutely black. Heated in a borax bead the patina disappears, and the borax on cooling assumes a faint greenish tint. The platinum acquires a silvery metallic appearance. The removal of the patina discloses the presence of minute hollows filled with a black mineral which the authors believe to be chromite. Precisely similar grains are found associated with chromite in the Urals. Microchemical tests revealed the presence of osmium, platinum, palladium, copper, iron, and nickel. The largest specimen examined weighed ·02338 gram; but M. Orueta has obtained much larger ones and also a small nugget weighing 2 grams.

The authors then describe two or three of the typical Russian occurrences, laying special emphasis on the differences between the two localities. In the Urals dunite is developed on a much more extensive scale. It forms large more or less elliptical masses surrounded by a fringe of pyroxenic rocks which are, in their turn, surrounded by gabbro. In the Sierra de Ronda the dominant peridotite contains a rhombic pyroxene, and the mass is directly surrounded by metamorphic rocks into which the peridotites have been intruded. Dunites occur in both localities, but in the Urals they are, as a rule, sharply separated from the pyroxenites, whereas in the Sierra de Ronda they pass gradually into peridotites with pyroxene. The alluvial deposits also present important differences.

The memoir concludes with the description of the peridotites of Khrebet-Salatin, in the northern part of the Urals, which differ in their mode of occurrence from those of the classical platiniferous localities and resemble those of the Sierra de Ronda. Platinum has been found in the alluvia of rivers draining Khrebet-Salatin, but no satisfactory results from the economic point of view have as yet been obtained.

Although the result of the comparison of the typical platiniferous localities of the Urals with the Sierra de Ronda is not exactly encouraging, it is to be hoped that M. Orueta's interesting discovery will be followed up, and that it will lead to an important addition to the world's supply of platinum.

IV.—Geology and Petrography of the Urals. Recherches Géologiques et Pétrographiques sur l'Oural du Nord: le Bassin des Rivières Wagran et Kakwa. Par Louis Duparc et Margarite Tikanowitch. Mém. Soc. Phys. Hist. Nat. Genève; Quatrième Mémoire, pp. 69–168, avec 11 figures et 2 planches.

THIS memoir consists mainly of detailed petrographical descriptions of rocks collected during explorations made in 1903. The district lies to the east of the main watershed of the Urals and is traversed by lat. 60° N. No detailed map exists, and the country, which is largely covered with forest, is practically uninhabited.

Passing eastward from the line which separates the rivers of Europe from those of Asia one traverses a zone of quartzose schists and quartzites, the latter forming anticlinals in the former. This is succeeded by a zone of hornblende rocks, more or less schistose, some of which appear to have belonged originally to the diabase family. On the right bank of the Wagran green quartzose schists are followed by plutonic rocks, consisting of gabbro-diorites, quartz-diorites, and granites with plagioclase. Normal fresh gabbros are also present on an extensive scale, but pyroxenites and dunites are comparatively rare, and when they do occur the pyroxenites do not form a zone round the dunites as they do in other parts of the Urals. The dyke rocks include beerbachites with hornblende, diorite-porphyrites, and a peculiar rock, intrusive in dunite, to which the authors apply the name of gladkaite. This is a fine-grained rock composed of apatite, magnetite, biotite, muscovite, hornblende, epidote, quartz, and plagioclase felspars, which vary in composition from labradorite to oligoclase-andesine, andesine being the dominant variety.

The petrographical descriptions, which make up more than two-thirds of the memoir, are full of details as to the birefringence and other optical characters of the minerals. Numerous chemical analyses are given, but they are not up to the standard of the best modern work, and the name of the analyst is not mentioned.

V.—A Lower Devonian Fauna of the United States.

The Fauna of the Chapman Sandstone of Maine, including Descriptions of some Related Species from the Moose River Sandstone. By Henry Shaler Williams, assisted by Carpel Leventhal Breger. Professional Paper 89, Department of the Interior, United States Geological Survey (George Otis Smith, Director). pp. 347, with 27 plates. 1916.

THE principal author of this monograph, Professor H. S. Williams, has for long been an authority on the Palæozoic rocks and fossils of Maine, in the endeavour to trace a relationship between the well-known Upper Palæozoic of Europe and that of the interior of the North American Continent. In the volume before us we are introduced to an extensive fauna belonging to the Chapman Sandstone formation of Maine, which is regarded as possessing an intermediate facies and so "linking together the faunas of New York and those of the Tilestone, or terminal Silurian, of Great Britain". In the study of British collections it was found that hardly any of the species were actually identical with those of the Chapman fauna, although many showed marked affinities. For purposes of comparison, the closely related fauna of the Moose River Sandstone exposed in Central and Northern Maine is also considered, but not exhaustively, only a few new species being now described. Some further forms from typical regions of Aroostook County, Maine, are also included. The major part of the memoir is taken up with minute descriptions of the species which, according to Professor Williams, has been mostly the work of his assistant, Mr. C. L. Breger. More than a hundred species are discussed belonging to the groups Cephalopoda, Gastropoda, Pelecypoda, Trilobita, Ostracoda, and some Plant remains (? *Psilophyton*), as well as a fish fragment (*Asterolepis clarkei*, Eastman), the Brachiopods and Pelecypods being, however, the more abundant organisms. Some fifty or more new species are established, together with the following new genera and sub-genera—**Pelecypoda**: Preavicula type = *Megambonia oblonga*, Hall; Sphenotomorpha type = *S. rigidula*, n.sp.; Grammysioidea type = *G. princiana*, n.sp.; Nuculoidea type = *Nucula opima*, Hall. **Brachiopoda**: Antispirifer type = *A. harroldi*, n.sp. **Ostracoda**: Zygobeyrichia type = *Z. apicalis*, n.sp., and including also *Beyrichia devonica* of Jones & Woodward, from the Lower Devonian of England.

The fauna of the Chapman Sandstone is regarded as of true Lower Devonian age, with affinities to the Helderbergian fauna of New York, but characterized by more numerous European types than the typical Helderbergian. Compared with Europe, the Chapman fauna shows affinities with the Lower Devonian, particularly that portion of it below the Upper Coblenzian. It is, moreover, said to be a later fauna than the Tilestone or Downtonian of England, or the terminal marine fauna of Arisaig, Nova Scotia, being besides recognized as of earlier age than that of the Moose River Sandstone, which may be correlated with the Oriskany Sandstone of New York and the York River (Gaspe Sandstone) of Gaspe Peninsula.

In a footnote on p. 27 the date of *Leptæna explanata* by J. de C.

Sowerby is called in question, a species from the Rhenish Lower Devonian described and figured in an "Appendix" to a memoir by Archiac & Verneuil on that subject published in the Trans. Geol. Soc., London, vol. vi, pt. ii, p. 409, pl. xxxviii, fig. 15, 1842. On p. 410, and immediately following Sowerby's Appendix, is a concluding note by Archiac & Verneuil, dated September 10, 1842, which would indicate that this part of the Transactions was issued fairly late in 1842. The reviewer's own copy of this work has the original wrappers preserved, so that there is no doubt as to 1842 being the year of publication of this particular part.

The European species is tentatively regarded as being synonymous with Conrad's *Strophomena perplana*, which, according to the present memoir, "is known to have been published early in 1842." It would follow, therefore, that if this synonymy is adopted Conrad's name should be preferred, as Sowerby's *explanata* was not established until a much later period of that year. Although we consider that much of the descriptive work might have been more briefly stated, and the synonymic lists reduced in many instances, the memoir is, doubtless, a great contribution to geological science, and we heartily commend it to all interested in Devonian faunas.

R. B. N.

VI.—Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1915.

On the North Wales border work was continued to the southern termination of the Denbighshire coalfield, and the mapping of the neighbourhood of Shrewsbury was commenced. In Warwickshire the surveying of the Upper Red Coal-measures was completed as far south as Coventry, and this has rendered possible a revision of the estimates of the depth and resources of the concealed coalfield. Thirty-eight square miles may now be added to the area, as estimated by the last Coal Commission, within which the coals probably lie between 2,000 and 3,000 feet below the surface.

In Staffordshire an area of four square miles, hitherto supposed to be overspread by Bunter, has been found to consist mainly of the Upper Coal-measures supporting small outliers of Bunter Sandstone.

In Scotland field work was carried on in the basaltic plateau of Mull, near Tobermory, in the Central Highlands, near Dalwhinnie, and in the coalfields of Ayrshire, Lanarkshire, and Renfrewshire. But the carrying out of the original plans was much interfered with by special investigations connected directly or indirectly with the War.

The report on the chemical researches contains full analyses of eighteen igneous rocks, two from Lundy Island and the remainder from Mull. It also contains an account of some interesting investigations on clays made in the Government Laboratory, Clement's Inn Passage. "Rational" and "Ultimate" analyses of seven clays were made, and a comparison of the results shows "that the felspar found in the 'Rational' analysis is in all cases very much lower than that calculated on the assumption that all the sodium and potassium oxide is present as felspar. The values for quartz are very much closer and in five cases are in satisfactory agreement".

The "Summary" also contains appendices dealing with (1) a deep boring for coal near Little Missenden, Bucks, and (2) a Catalogue of Types and Figured Specimens of British Cretaceous Gasteropoda preserved in the Museum of Practical Geology.

VII.—Economic Geology. By Heinrich Ries, A.M., Ph.D., Professor of Geology at Cornell University. Fourth edition, thoroughly revised and enlarged. pp. xx + 856, 6″ by 9″, with 291 figures and 75 plates. New York, John Wiley & Sons; London, Chapman & Hall, Ltd. 1916. $4·00 net.

THIS is a revised and enlarged edition of Professor Ries' well established book, written especially for American teachers and students, on Economic Geology. Like the previous editions it gives concise descriptions of the composition, mode of occurrence and origin of the economically valuable rocks and minerals of the United States, to which have now been added descriptions of the more important Canadian deposits, and brief references to those of other countries. The latest available statistics of production have been included and each section is accompanied by a valuable bibliography, dealing especially with North American occurrences. The book has been brought up-to-date, and is well illustrated by sections, maps, and photographs.

VIII.—Origin of the Zinc and Lead Deposits of the Joplin Region. By C. E. Sienbenthal. Bulletin 606 United States Geological Survey. Washington, Government Printing Office, 1915. pp. 283, with 9 plates and 16 figures in the text.

FOR some dozen years the author was engaged in studying the famous zinc and lead deposits of the Joplin region. Besides their great economic importance these deposits have long been of intense interest to students of ore deposition, because they form a conspicuous example of the occurrence of sulphide ores in a region where apparently no plutonic or volcanic activities can have played a part in their genesis. Mr. Sienbenthal has carefully considered and tested the numerous theories that have been put forward from time to time by other observers, and has come to the conclusion that the ores were segregated by artesian—circulating alkaline—saline sulphuretted waters from zinc and lead minerals disseminated in the Cambrian and Ordovician limestones of the Ozark uplift, which is a low asymmetric dome, rudely elliptical in outline, lying in southern Missouri, northern Arkansas, south-eastern Kansas, and north-eastern Oklahoma. The great mass of the ores appear to have been conveyed as bicarbonates, and to have been precipitated as soon as the water bearing them reached the surface and gave up the carbonic acid dissolved in it. The data upon which his conclusions are based are very fully set forth. The memoir is one that should be studied by all those interested in the question of the genesis of ore deposits.

IX.—Preliminary Report on the Mineral Production of Canada during the calendar year 1915. By John McLeish. Ottawa, Government Printing Bureau, 1916. pp. 28.

THE report reveals very clearly how greatly the mineral industry was stimulated by the War, the demand for the metals copper, lead, nickel, and zinc being specially great. The steel furnaces were worked to their utmost capacity. Further, the development of smelting and refining operations has been greatly stimulated, since it was desirable that for such necessary adjuncts the country should not be dependent on even a friendly neutral country. The production of copper increased 72, of lead 56, and nickel 49½ per cent in value. Canada produced during the year nearly 3 million dollars worth of gold.

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *February* 7, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Trias of New Zealand." By Charles Taylor Trechmann, M.Sc., F.G.S.

The fossiliferous Triassic rocks of New Zealand have been wholly or in part at different times attributed by the geologists of that Dominion to a Devonian, Permian, Permo-Carboniferous, Lower, Middle, or Upper Triassic, or Trias–Jura age. A review of the previous research on these rocks and of their correlation and nomenclature is given. They are quite distinct from the Matai rocks, which contain a Permo-Carboniferous fauna.

Triassic beds appear at intervals from Kawhia on the western coast of the North Island to Nugget Point on the south-eastern coast of the South Island—a distance of 620 miles. Except in two localities, they are everywhere very steeply inclined, and where they approach the Alpine Chain of the South Island pass into semi-metamorphic greywackes or completely metamorphic phyllites and schists. They are of great thickness. A short description of the special faunal, lithic, and tectonic features of each of the more important localities is given, all of which but one occur in the South Island. In the North Island only the Noric and Rhætic horizons have been recognized. Wherever the sequence is preserved, the Trias passes conformably up into Jurassic deposits.

The lowest fossiliferous horizon of the Trias occurs near the top of a great thickness of greywackes and conglomerates called the Kaihiku Series, and is separated by several hundred feet from the next fossiliferous beds above it. The Kaihiku fossils are scanty in species, and no Cephalopods occur. Among those restricted to this horizon is *Daonella indica*, Bittner, which occurs in Ladino-Carnic deposits in the Himalayas and in the Malay Archipelago. Members or survivors of a Muschelkalk fauna occur in the form of *Spiriferinæ* of the group of *Spiriferina fragilis*, Schlotheim. It is concluded that the Kaihiku fossil horizon is either late Middle or early Upper Trias, and the great unfossiliferous series below it represents the Middle and possibly Lower Trias.

The most highly fossiliferous division is the Carnic—the Oreti and Wairoa Series of New Zealand geologists. Several Ammonites occur, among which *Discophyllites* cf. *ebneri*, Mojsisovics, is found in the Carnic and Lower Noric of the Himalayas. The *Halobiæ* include *H. zitteli*, Lindström, a Spitsbergen fossil, together with *H. hochstetteri*, Mojsisovics, and *H. austriaca*, Mojsisovics. Several of the Carnic fossils show affinities with European Alpine forms, and can be used for purposes of correlation.

The Noric horizon, the Otapiri Series in part, is represented by felspathic sandstones containing immense quantities of *Pseudomonotis*, a genus which characterizes the Noric in all the Circum-Pacific Trias. *Ps. richmondiana*, Zittel, is known only from New Zealand and New Caledonia; but the author found the Asiatic, Siberian, and Japanese form *Ps. ochotica*, Teller, in all its varieties, in very high Noric beds near Nelson.

The Rhætic, the upper part of the Otapiri Series of local geologists, comprises a great thickness of sandy and pebbly beds. Its fossils include an extremely alate *Spiriferina* and a group of specialized bisulcate Spirigerids. An Arcestid of Rhætic aspect was collected high up in these beds at Kawhia.

Forty-seven genera and species of molluscs and Brachiopods are recorded in the present paper, of which three genera and forty-one species are regarded as new.

The Brachiopods are of considerable interest, and exhibit phylogerontic tendencies in several of the groups as they approach extinction.

The affinities of the New Zealand Trias with that of the Malay Archipelago, and especially of New Caledonia, is discussed; and it is shown that the faunal transgression which occurred over those regions, at or shortly before the commencement of Upper Triassic times, extended also to the area now occupied by New Zealand.

In the discussion which followed, the author stated that the true relationship of the Mount Torlesse Annelid Beds was still one of the unsolved problems of New Zealand geology. The question of their stratigraphy is discussed by McKay and others, and the evidence seems to show that they form the upper part of the Maitai Series. The Annelid Beds have not been traced in the Nelson district, the classical area of the Maitai Series; but he had himself found a piece of annelid-like tube in the Maitai Limestone of the Wairoa Gorge, accompanied by *Zaphrentis* and Permo-Carboniferous Brachiopods.

He did not think the Mount Torlesse Annelid Beds in any way equivalent to the Yakutat Slates of Alaska, as he had shown that the large bivalve in the Maitai Argillites overlying the Limestone near Nelson, formerly supposed to be *Inoceramus*, is apparently identical with *Aphanaia*, de Koninck, of the Permo-Carboniferous of New South Wales.

Inoceramya, Ulrich, of the Yakutat Slates, is a shell of the

Inoceramus group, and bears a row of areal ligament pits. The Lias, or at least the Lower Jurassic, is a well-defined formation in New Zealand, where it overlies the Trias, and in no way resembles the Annelid Beds.

He felt much interest in the fact that Dr. Bather had determined the scanty crinoid remains that he collected in the Kaihiku Beds as rather of Upper than of Middle Triassic age. All evidence that these deposits were Permian or Lower Trias seemed now entirely removed.

2. "The Triassic Crinoids from New Zealand collected by Mr. C. T. Trechmann." By Francis Arthur Bather, M.A., D.Sc., F.R.S., F.G.S.

The specimens are all from the Kaihiku Series, and comprise: (1) an *Entrochus* from near Nelson, with a broadly waved suture: (2) a rock-fragment from the Hokanui Hills, containing imprints of columnals and brachials representing two genera: namely, (*a*) an *Entrochus* with ridges of the joint-face arranged in pairs separated by shorter ridges; (*b*) an *Isocrinus*, of the group of *I. dubius* (Goldfuss). Comparison of the three new species based on all these remains with the Triassic crinoids described from Europe and especially with those from North America, leads to the conclusion that they are of Upper Triassic age. They bear, however, no resemblance to the Upper Triassic crinoids from Timor, which the author has in hand for description.

3. "On a Spilitic Facies of Lower Carboniferous Lava-flow in Derbyshire." By Henry Cruden Sargent, F.G.S.

The igneous rocks of Derbyshire form a basic series, consisting mainly of lavas and sills, hitherto classed as olivine-dolerites and basalts, often associated with tuffs and agglomerates. All these rocks occur in Lower Carboniferous strata. The lavas were submarine and contemporaneous.

Specimens of the lavas from certain localities exhibit a trachytic structure, and possess affinities with both spilites and mugearites. These specimens are all intensely decomposed, felspar being generally the only original mineral that is determinable. The alkali content sometimes exceeds 7 per cent, potash being always important and sometimes predominant. The felspar species are oligoclase and orthoclase, with generally a more basic plagioclase subordinate. Replacement by alkali-felspar frequently occurs.

Field evidence shows that these spilitic rocks, as a rule, underlie the basalts. A gradation may be traced between the two extremes of the series.

It is suggested that the whole series has been derived from a common magma of normal basaltic type, and that, by the upward passage of gases through the magma, a relative concentration of the alkalies took place in its upper part, which was the earliest erupted.

It is further suggested that the intense decomposition of the spilites is a case of auto-metamorphism, due to retention of volatile constituents resulting from the physical environment of a submarine flow.

An analogue to the radiolarian cherts and jaspers, generally associated with spilites in other localities, is found in Derbyshire, in the quartz-rock and other siliceous rocks that frequently occur in proximity to volcanic vents.

Since the spilites appear to be differentiates from a normal basaltic magma, resulting largely from their physical environment, it is concluded that they do not form a separate suite of igneous rocks distinct from other alkaline rocks.

Annual General Meeting.

2. *February* 16, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The reports of the Council and the Library Committee were read. It was stated that 34 Fellows were elected in 1916 (3 more than in 1915). During the same period, the losses by death, resignation, and removal amounted to 66, the actual decrease in the number of Fellows being 32. The total number of Fellows on December 31, 1916, was 1231.

The balance-sheet for that year showed receipts to the amount of £2,668 3*s.* 1*d.* (excluding the balance of £635 13*s.* 4*d.* brought forward from 1915) and an expenditure of £2,627 4*s.*

Reference was made to the decease of the Treasurer, Mr. Bedford McNeill, and to the election, in his place, of Dr. J. V. Elsden.

The awards of the various Medals and Proceeds of Donation Funds in the gift of the Council were enumerated in the Geological Magazine for March, 1917, p. 140.

The Reports having been received, the President handed the Wollaston Medal, awarded to Professor Antoine François Alfred Lacroix, F.M.G.S., to Sir Archibald Geikie, O.M., for transmission to the recipient, addressing him as follows:—

Sir Archibald Geikie,—For a Medal instituted "to promote researches concerning the mineral structure of the Earth" it would be difficult to find a fitter recipient than Professor Lacroix, to whose labours in the domain of mineralogy and petrology our science is so deeply indebted. His researches on the optical and crystallographic constants of numerous minerals have given us a mass of useful data; but it has always been his practice to extend his investigations to the field as well as to the laboratory. His studies of the mode of occurrence, the mutual associations, and the manner of origin of a host of species have done much to rehabilitate mineralogy as, not merely a department of physics and chemistry, but a fascinating branch of natural history. His many separate papers deal with material from all parts of the world; but of chief importance will always be reckoned his four volumes on the mineralogy of France and her Colonies, a single-handed work unique in its wide scope and comprehensive treatment.

In petrology, too, Professor Lacroix's contributions have been numerous and many-sided. Of special note for their influence upon the science are his researches on contact-metamorphism, contained in bulletins of the Geological Survey of France, his various memoirs treating of the inclusions in igneous rocks, and his comparative study of the volcanic products of Mont Pelé, followed by a like examination of the rocks of Vesuvius.

From the products of volcanoes to the physics of volcanic action is a natural transition, and in respect of both Professor Lacroix's mission to Martinique in 1902 was eminently fruitful in results. In particular he was able to elucidate two remarkable phenomena previously unrecognized or unappreciated, the peculiar plugs or domes formed under certain conditions by extruded lavas and that most terrible of all volcanic effects, the *nuée ardente.*

As a diligent student of his writings, I feel a special pleasure in placing the Wollaston Medal in your hands for transmission to Professor Lacroix. With no less pleasure, I am sure, will all British geologists see his name added to a list which is already graced by the names of Élie de Beaumont and Ami Boué, Daubrée and Des Cloizeaux; and they will acclaim this award the more cordially since, in doing homage to a distinguished savant, we are honouring a citizen of a great nation, with which our own is linked, as we hope, by enduring ties.

Sir Archibald Geikie replied:—

Mr. President,—It is both a signal honour and a welcome pleasure to me to have been requested by my friend Professor Lacroix to receive this Medal on his behalf. He has asked me to express to you and to the Society his grateful thanks that you should have thought him worthy of your highest prize, and at the same time to assure you how deep is his regret that his official engagements prevent him from leaving Paris and being with us here to-day. You are aware that he has now added to his ordinary professional duties those of Secrétaire Perpétuel de l'Académie des Sciences, thus following, at no great interval of time, another eminent geologist of France, our lamented Foreign Member De Lapparent.

You have sketched with well-merited appreciation the wide range of investigation through which our latest Wollaston Medallist has pursued his studies. He has united with pre-eminent skill the detailed work of the laboratory with an appeal to the essential evidence which can only be obtained in the field. In this latter branch of research he has been fortunate in having as his companion and fellow-labourer a devoted and enthusiastic wife. Madame Lacroix, as the daughter of Ferdinand Fouqué, has inherited her father's scientific ardour, and has proved herself to be as capable and enduring a mountaineer as her husband.

Professor Lacroix has sent me a brief address to you, Mr. President, expressive of his grateful recognition of the honour which the Geological Society has conferred upon him. I have ventured to make a translation of this address, which I will now read:—

"Mr. President,—No honour could be more appreciated by me than that which the Geological Society of London has conferred upon me. Over and above the pride which I feel in this award from so many competent judges, among whom are not a few who pursue the same researches as those to which I have devoted myself, there is added, in present circumstances, the further gratification to see the ties strengthened which from old times have linked the men of science in our two countries—Britain now striving, with all her power and all her soul, hand in hand with France in defence of Right and Liberty.

"You have wished this year, I am sure, to honour in a more special manner French geology, and this adds a further reason why I should be touched that you have chosen me as the recipient of your prize.

"In being so good as to represent me at your anniversary, Sir Archibald Geikie, for whose work I have as great an admiration as I have respectful esteem for him personally, will convey to you, as far as that is possible, my regret that my official duties here prevent me from being present with you, and expressing with my own living voice all my gratitude.

"Among the distant memories of my student days there rises in my mind the recollection of my old and dear master Des Cloizeaux (the friend of your Professor Miller) carefully taking out of a drawer in his writing-table the Wollaston Medal which he had some time before received from you, and showing it to his pupils as one of the most valuable tokens of esteem that he had ever received in the course of his long and laborious career.

"How, indeed, could one not be proud, though with all humility, to see one's name inscribed in your golden book below those of the founders of our science, and following those among you who with such brilliance continue to maintain their great and glorious inheritance?

"Be so good, Mr. President, as to receive the expression of my highest consideration.

"A. LACROIX."

In handing the Murchison Medal, awarded to Dr. George Frederic Matthew, to Dr. J. E. Marr, for transmission to the recipient, the President addressed him as follows:—

Dr. MARR,—In awarding the Murchison Medal to Dr. G. F. Matthew the Council desires to mark its high appreciation of the services which he has rendered to geology, more particularly by his researches among the Lower Palæozoic rocks of New Brunswick.

Engaged for many years in official duties, and enjoying little of the advantages which come from association with fellow-workers and from access to large libraries and museums, he has still found time and means to make valuable contributions to our science. So long ago as 1865 he communicated an important paper to this Society, but most of his results have seen the light in Canadian and American journals. Of first importance must be reckoned his *Illustrations of the Fauna of the St. John Group*, published by the Royal Society of Canada, a work embodying much patient and skilful research. A paper which appeared in 1895, in the Transactions of the New York Academy of Sciences, contained the first account of the *Protolenus* fauna. Of other important contributions which Dr. Matthew has made to Lower Palæozoic geology I may mention his discoveries of the Etchiminian and the still older Coldbrook fauna beneath what had previously been considered the oldest fossiliferous horizon in New Brunswick. His work has been distinguished throughout by a happy combination of stratigraphical skill with palæontological knowledge, and some of his studies, such as those on the evolution of the Cambrian Trilobites, have had far-reaching consequences.

I have much pleasure in handing this Medal to you for transmission to the veteran Canadian geologist, and hope that he will see in it a token that his labours in the field of science are not without recognition in this country.

Dr. Marr replied:—

Mr. President,—The interval that has elapsed since the award of the Murchison Medal has been too short, in these times of stress, to allow Dr. Matthew to send an acknowledgment. Had he done so he would doubtless have expressed to the Council his gratification at the honour conferred upon him.

I am glad to receive the Medal on his behalf, so that I, an old friend, may add my appreciation of the value of his work, although this is unnecessary after the sympathetic words which you, Sir, have offered concerning it.

Dr. Matthew's name is the latest in a long list of Canadians on our roll of honour, for the men of the Dominion have excelled in the field of our science, as latterly in another and a sterner field.

I feel that I may, on behalf of the Fellows of the Society, express the wish that our Medallist, veteran though he be, may yet enjoy many years in the study of his favourite science.

The President then handed the Lyell Medal, awarded to Dr. Wheelton Hind, F.R.C.S., to Dr. A. Smith Woodward, for transmission to the recipient, addressing him as follows:—

Dr. SMITH WOODWARD,—The Lyell Medal has been awarded by the Council to Dr. Wheelton Hind as a token that he has, in the words of its founder, "deserved well of the science."

On the side of descriptive and systematic palæontology his two memoirs on the Carboniferous Lamellibranchiata, published by the Palæontographical

Society, have long taken rank as standard works, and he has supplemented them from time to time by many other contributions dealing with the same subject. Further, he has brought his palæontological knowledge to bear upon important questions of stratigraphy, and has shown that the lamellibranch faunas of different groups of rocks furnish valuable data for purposes of comparison. In this way he has taken no small part in the correlation of the Carboniferous strata in different areas in Britain, and has further pushed his inquiries to the Continent of Europe.

The quantity, as well as the quality, of his geological work seems the more remarkable when we remember that his researches have been carried out in the intervals, none too frequent, of a busy professional life. In conferring upon him this mark of recognition, so well earned, we are thus honouring one of those amateur workers to whom British geology has always been signally indebted. In presenting it I express the hope that, when happier days bring again some allowance of leisure, Dr. Hind will be able to renew those investigations which have already proved so rich in results.

Dr. Smith Woodward replied in the following words:—

Mr. President,—I shall have much pleasure in transmitting the Lyell Medal to my friend Dr. Wheelton Hind, on whom it has been so worthily bestowed. Geological science has always been greatly indebted to the medical profession for important advances made in their brief intervals of leisure, and Dr. Hind has for many years excellently maintained the old tradition. Recognizing the importance of combining work in the field with detailed palæontological research in the study, he soon became one of the most successful exponents of the modern methods of stratigraphical geology. Beginning researches on the Carboniferous rocks in his own district of North Staffordshire, he has gradually extended his domain until, as you have well said, Sir, he has taken no small part in the correlation of the Carboniferous strata of Britain. As soon as he is released from the military duties which prevent his attendance at the meeting to-day, I feel sure that Dr. Hind will return with renewed vigour to the geological work which has so long been his recreation; and he desires me to express his best thanks to the Council of the Geological Society for the stimulating award with which they have honoured him.

In handing the Bigsby Medal, awarded to Mr. Robert George Carruthers, to Dr. A. Strahan, Director of H.M. Geological Survey, for transmission to the recipient, the President addressed him as follows:—

Dr. Strahan,—The Bigsby Medal has been awarded to Mr. Carruthers by the Council as an acknowledgment of his eminent services to Scottish geology. As an officer of the Geological Survey he has investigated considerable areas of the ancient rocks of the Highlands, the Carboniferous of the Scottish Midlands, and the Old Red Sandstone of Caithness; and in each of these fields his labours have yielded results which possess more than a local interest. On the side of pure palæontology he has made important additions to our knowledge of the Corals, in particular by his memoir dealing with the morphology of the Rugosa; but especially are geologists indebted to him for the use which he has made of the Corals in the zonal subdivision of the Carboniferous succession. Of other palæontological contributions having a direct stratigraphical application, I will recall only his discovery of a Pendleside fauna in the Calciferous Sandstone Series of Lanarkshire and his reference of the fish-fauna of Achanarras to its true position in the Old Red Sandstone sequence. Among his services to economic geology his revision of the memoir on the oil-shale fields of the Lothians is especially worthy of mention.

The founder of this Medal, in fixing an age limit for the recipient, made clear his intention that regard should be had, not only to performance in the past, but to promise for the future. Confident that in this case the one is a sure guarantee of the other, we ask him to receive this award in the double acceptation of a tribute and an encouragement.

Dr. Strahan replied :—

Mr. President,—It is a great pleasure to me to receive, on behalf of my colleague on the Geological Survey, this testimony of the value that the Council attaches to his work. You have referred in generous terms to Mr. Carruthers's contributions to our knowledge of Scottish geology, and to his researches in pure palæontology. His application of scientific methods of investigation to corals has done much to elucidate stages of evolution in those lowly organisms, and I believe that your recognition of this branch of his work will be especially gratifying to him. In economic geology the demands made upon the staff by the exigencies of war were sudden and imperative, and no one knows better than myself how well Mr. Carruthers and his colleagues responded to the call, and for the time resisted the fascinations of abstract science.

Mr. Carruthers, writing amid the distractions of the Western Front, tells me that it is

"almost impossible to give any adequate expression of my gratitude to the Society for their award of the Medal. . . . As the bulk of my work has been concerned with economic geology, the honour of this award is shared equally with my comrades on the Survey. . . . In the field of abstract science my ventures have been little more than tentative. I hope that the generous encouragement that they have always received from the Society may ultimately be repaid in some degree. The obligation is, of course, greatly increased by this additional proof of trust".

May I express the hope, for myself and for the Fellows of the Society, that it will not be long before Mr. Carruthers can resume his scientific work and justify the confidence that you have so gracefully expressed in his promise for the future?

In presenting the Balance of the Proceeds of the Wollaston Donation Fund to Percy George Hamnall Boswell, D.Sc., the President said :—

Dr. Boswell,—The Balance of the Proceeds of the Wollaston Donation Fund has been awarded to you by the Council in recognition of your work in East Anglia, by which you have added to our knowledge of the subterranean as well as the superficial geology of that area. In your earlier contributions you examined the origin of the existing river-system of Suffolk, and also endeavoured to define the limits of extension of the Lower Glacial deposits of Norfolk into the more southerly county. You have also made instructive researches into the lithology and mineralogy of many of the sedimentary deposits of East Anglia. In a paper read before this Society two years ago you employed this method, in conjunction with stratigraphical observation, in a comprehensive study of the Lower Eocene strata of the area, and drew interesting conclusions concerning the geography of the period and even the tectonics of the country. Your more recent investigations concerning sands suitable for glass-making have a direct practical application of much importance at the present time.

Some part of your work has been the outcome of a grant from the Daniel Pidgeon Fund, and the good use which you made of that opportunity assures us that you will regard the present award as an incentive to new enterprises in the service of Geology.

The President then handed the Balance of the Proceeds of the Murchison Geological Fund, awarded to Dr. William Mackie, to Dr. W. T. Gordon, for transmission to the recipient, said :—

Dr. Gordon,—The Balance of the Proceeds of the Murchison Geological Fund has been awarded by the Council to Dr. Mackie in recognition of his contributions to the geology of Northern Scotland. A skilled chemist as well as a keen petrologist, he has utilized in this way his leisure as a medical practitioner during the last twenty years.

By his investigation of the sandstones of Eastern Moray he has thrown light, both on the source of the material and on the climatic conditions which prevailed during its deposition. In the cement of these sandstones he detected traces of the heavy metals, and his inquiry led to the discovery in quantity of barytes and fluor in the Elgin Trias. His petrographical work includes an interesting study of the granites of the North of Scotland, and he has also carried out a large series of chemical analyses of igneous and sedimentary rocks in order to elucidate theoretical questions suggested in the course of his researches.

His recent discovery of plant-bearing cherts in the Old Red Sandstone of Rhynie (Aberdeenshire), has added a new interest to that formation. Dr. Kidston and Professor Lang recognize these cherts as silicified layers of peat, and a new class of vascular Cryptogams, the Psilophytales, has been made for the reception of the plants which they contain.

I ask you, in forwarding this award to Dr. Mackie, to convey to him our hope that he will thereby be encouraged to continue the researches which he has hitherto pursued with such enthusiasm.

The President then presented a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Arthur Hubert Cox, Ph.D., said :—

Dr. Cox,—The Council has awarded to you one moiety of the Proceeds of the Lyell Fund in recognition of the value of your work among the Lower Palæozoic rocks. Since you read before this Society, five years ago, a paper on the Pedwardine Inlier, you have devoted much time to geological researches in Wales, both South and North. Your paper on the Abereiddy and Abercastle district was a valuable contribution to the stratigraphy and tectonics of Pembrokeshire, and gave evidence of skilful and accurate work in the field. On the petrological side, too, it added to our knowledge of the Ordovician igneous rocks, a subject to which you have also given attention elsewhere. Your work in the Cader Idris district, of which we have as yet only a preliminary account, seems to be of the same thorough quality ; and, in thus marking our appreciation of what you have already done, we look forward to results not less important from your geological labours in the time to come.

In handing the other moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Tressilian Charles Nicholas, M.A., to Mr. H. Woods, for transmission to the recipient, the President said :—

Mr. Woods,—A moiety of the Proceeds of the Lyell Fund has been awarded to Mr. T. C. Nicholas as a mark of appreciation of his work on the older Palæozoic rocks of Carnarvonshire. The results of that work are represented firstly by a paper on the Geology of the St. Tudwal's Peninsula, in Lleyn, read before this Society in 1914. Therein he gave a comprehensive account of the succession, fossil contents, and classification of the Cambrian strata of the district, and established the unconformity which exists between these beds and the overlying Ordovician. This paper was supplemented in the same year by a palæontological one dealing with the rich trilobitic fauna, of Middle Cambrian age, which his researches had discovered. A number of new and interesting species were described, and the succession of forms was correlated with that recorded for other areas.

As an old friend of Mr. Nicholas, and one who has seen something of the difficulties presented by the Lleyn district, I am pleased that it falls to my lot to extend to him, on behalf of the Council, this token of recognition of his geological and palæontological work.

The President then presented the Balance of the Proceeds of the Barlow-Jameson Fund to Mr. Henry Dewey, said:—

Mr. Dewey,—The Proceeds of the Barlow-Jameson Fund have been awarded to you in recognition of your services to Geology and as an encouragement to you for the future. In the record of your geological work the first place belongs to your researches in North Cornwall, where you were engaged as an officer of the Geological Survey. There your mapping led you to recognize a number of subdivisions of the Devonian strata and to determine their natural sequence, and with this help you were able to demonstrate the existence of important overthrusts in that area. The peculiar features of the 'pillow-lavas' intercalated in the Upper Devonian also engaged your attention, and your paper on the 'spilitic series', written in collaboration with Dr. Flett, has proved a valuable contribution to petrology. Of not less consequence, of another kind, were your paper on the Raised Beach of North Devon and that which you read before this Society a year ago on the Origin of River-gorges in Cornwall and Devon. Your removal from the West of England to the Thames Valley introduced you to new problems, to which you have brought the same zeal and insight, and it is our hope that you will find in the present award an incentive to further investigations in the field of Geology.

The President proceeded to read his Anniversary Address, including first obituary notices of Jules Gosselet (elected Foreign Member in 1885), J. W. Judd (el. Fellow 1865), J. H. Collins (el. 1869), C. T. Clough (el. 1875), Clement Reid (el. 1875), Bedford McNeill (el. 1888), H. Rosales (el. 1877), W. E. Koch (el. 1869), C. Dawson (el. 1885), T. de Courcy Meade (el. 1891), and others.

The remainder of the Address dealt with some aspects of igneous action in Britain, and especially its relation to crustal stress and displacement. This relation appears not only in the distribution of igneous activity in time and space, in the succession of episodes, the habits of intrusions, etc., but also in the petrographical facies of the igneous rocks themselves. The cause of such relation was sought in the existence of extensive inter-crustal regions in a partially molten state: that is, with some interstitial fluid magma, which must normally be rich in alkaline silicates. There will be a continual displacement of the interstitial magma from places of greater stress to places of less stress, and certain broad differences in chemical composition are therefore to be expected between the igneous rocks of orogenic belts and those erupted in connexion with gentle subsidence.

The Archæan plutonic rocks were intruded in close relation with powerful lateral thrust, and they accordingly include no alkaline types; but the Dalradian sediments were deposited in an area of tranquil subsidence, and the lavas intercalated in them are of the spilitic kind, rich in sodic felspars.

The Lower Palæozoic formations were laid down in a geosyncline, which for a long time experienced merely a slow depression, and the late Cambrian and early Ordovician eruptions, situated chiefly along the borders of the area, had a pronounced sodic facies. In mid-Ordovician times there entered a certain element of lateral thrust, and accordingly in the Llandeilian vulcanicity the spilitic type gave place to the andesitic; but the scattered outbreaks of Bala and Silurian age often afford evidence of a reversion to the earlier facies.

Following upon the great Caledonian crust-movements there was, in the Scottish Highlands and elsewhere, a copious intrusion of plutonic magmas, all of "calcic" as contrasted with alkaline types. The same characteristic belongs to the igneous rocks of the Lower Old Red Sandstone, which were extruded and intruded in connexion with the later Caledonian folding, while the country was still in a condition of stress. With the dying out of this stress a more alkaline facies supervened, and the Lower Carboniferous igneous rocks of Scotland, though developed largely in the same synclinal folds as the preceding series, present a strong contrast in petrographical characters. They indicate a certain richness in soda, and this feature becomes more pronounced, until it culminates in the Permian of Ayrshire and East Fife in highly alkaline rock-types.

In Southern England, remote from the main Caledonian disturbance, the Devonian and Carboniferous lavas are of the same spilitic type as those of the early Ordovician. Later, this part of the British area was involved in the Hercynian crust-movements, which were accompanied by the intrusion of the Cornish granites and their satellites.

In Mesozoic times our country experienced no orogenic disturbance of a pronounced type, and there was a prolonged cessation of igneous activity. The Tertiary Era introduced a new factor in the form of very extensive plateau-faulting, bearing no relation to the structure of the country. This movement, generally of the nature of subsidence, affected a vast area, of which Northern Britain is only a small fraction, and was attended by igneous action on the same extensive scale. The mechanism of extrusion and intrusion differed in important features from that illustrated by the Palæozoic eruptions. The Tertiary igneous rocks, as a whole, are decidedly, though not strikingly, rich in soda; but this alkaline character is lost in the neighbourhood of isolated centres, where there is evidence of locally developed stresses of an acute type.

The ballot for the Officers and Council was taken, and the following were declared duly elected for the ensuing year:—

Officers: *President*, Alfred Harker, M.A., LL.D., F.R.S. *Vice-Presidents*, R. Mountford Deeley, M. Inst. C. E.; Edwin Tulley Newton, F.R.S.; Professor William Johnson Sollas, M.A., LL.D., Sc.D., F.R.S.; and Arthur Smith Woodward, LL.D., F.R.S., F.L.S. *Secretaries*, Herbert Henry Thomas, M.A., Sc.D.; and Herbert Lapworth, D.Sc., M. Inst. C. E. *Foreign Secretary*, Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S. *Treasurer*, James Vincent Elsden, D.Sc.

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THE

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ASSISTED BY

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MAY, 1917.

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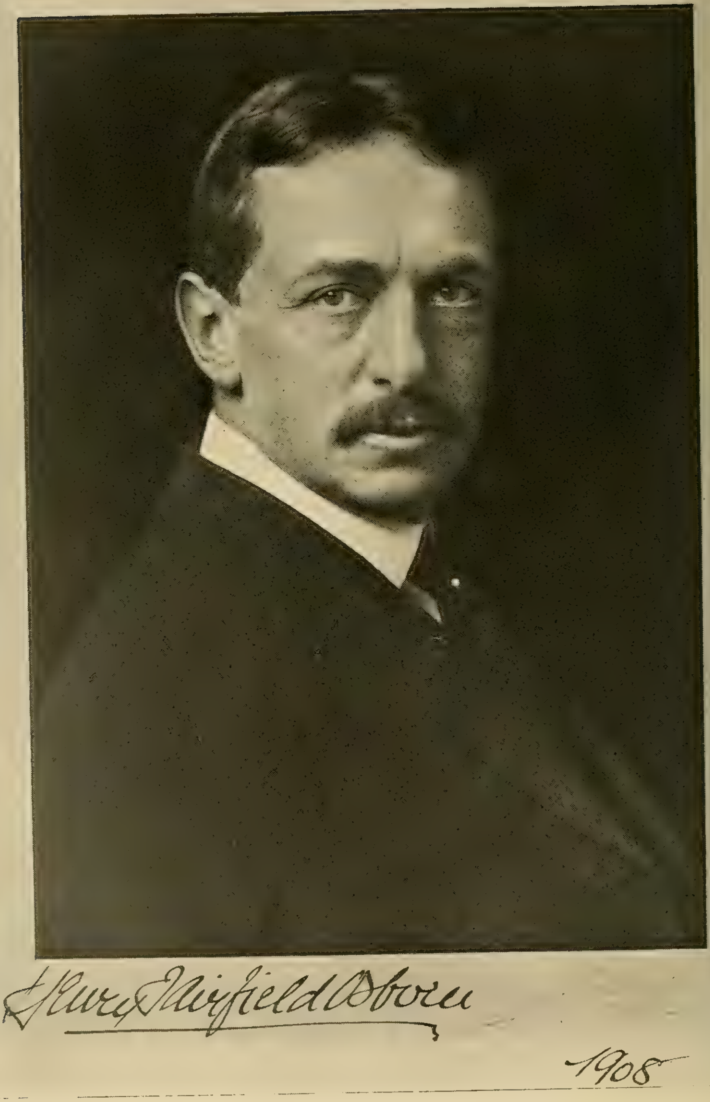

Henry Fairfield Osborn
1908

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. V.—MAY, 1917.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Henry Fairfield Osborn, LL.D. (Princeton, Columbia, Hartford), Sc.D. (Cambridge, Princeton), Ph.D. (Christiania), A.B. (Princeton); Foreign Member of the Linnean and Geological Societies of London; President of the American Museum of Natural History, New York.

(WITH PORTRAIT, PLATE XII.)

FOR nearly half a century geologists have followed with great interest and admiration the discoveries of fossil vertebrate animals in the west of North America. From the early days when western pioneers brought back scattered fragments for study by Leidy, to the seventies and eighties of last century when Cope and Marsh led or encouraged adventurous expeditions to collect fossils in the territories then occupied by hostile Indians, the continual succession of new forms of extinct reptiles, birds, and mammals met with in an unusual state of preservation, excited increasing attention. So remarkable, indeed, were these finds and so sporting was their pursuit, that rivalries arose and passed beyond the state of friendly emulation which is good for real progress. It was thus fortunate for American palæontology that a younger generation of well-trained enthusiastic students was then ready to enter the field, and especially fortunate that their leaders were imbued with a harmonious spirit of co-operation. Among these leaders was the subject of our present biographical sketch, who has perhaps done most by his personal influence to maintain the happy relations which now exist between all workers in vertebrate palæontology in America.

Henry Fairfield Osborn was born on August 8, 1857, at Fairfield, Connecticut, and began his education at the Lyons Collegiate Institute, New York. He next proceeded to Princeton University, where he graduated as A.B. in 1877. In 1879–80 he followed post-graduate studies under F. M. Balfour at Cambridge, and under Huxley at the Royal College of Science, London. In 1881 he became Assistant Professor of Natural Science at Princeton, and from 1883 to 1890 he was Professor of Comparative Anatomy in the same University. In 1891 he removed to New York, where he had been appointed Da Costa Professor of Biology in Columbia University and Curator of Vertebrate Palæontology in the American Museum of Natural History. In 1896 his Professorship was restricted to Zoology alone, and in 1910 he resigned both this and his Curatorship, being nominated Research Professor of Zoology in Columbia

University. In 1901 he was elected a Trustee of the American Museum of Natural History, and was second Vice-President from 1901 to 1908, when he assumed his present office of President of the Board of Trustees. In 1900 he succeeded Professor O. C. Marsh as Vertebrate Palæontologist to U.S. Geological Survey, and from 1900 to 1904 he was Vertebrate Palæontologist to the Geological Survey of Canada in succession to Professor E. D. Cope. In 1906 he was offered but declined the Secretaryship of the Smithsonian Institution, Washington.

Professor Osborn was specially trained as a zoologist, and several of his earlier papers relate to the structure and development of the brain. In association with his fellow-student, William Berryman Scott, however, his interest was soon aroused in extinct animals by the discoveries of Cope and Marsh; and in 1877 he began his life-work in palæontology by joining Scott and Francis Speir, jun., in an expedition to collect mammalian remains from the early Tertiary formations of Wyoming. On his second collecting trip in 1879, in the Washakie Eocene Basin of Wyoming, he recognized the possibility and importance of making more exact stratigraphical records than had previously been attempted; and from that time onwards he, with his pupils and associates, has paid so much attention to the stratigraphy of the deposits yielding vertebrate fossils, that the order of succession in each region explored is no longer a matter of inference and speculation but a definitely ascertained fact. It has thus become possible to use successive groups of vertebrate fossils with confidence when tracing changes in their peculiar characters through geological time; and many phenomena have become clear which would otherwise have been overlooked.

The precise determination of the relative ages of the extinct mammals in North America naturally suggested a reconsideration of the mammal-bearing Tertiary deposits in the Old World, and between 1898 and 1900 Professor Osborn obtained the help of several European palæontologists in preparing a table of "Correlation between Tertiary Mammal Horizons of Europe and America". As discoveries progressed he continued to improve this correlation, and it was extended and brought so far as possible up-to-date in his handsome volume, *The Age of Mammals in Europe, Asia, and North America*, published in 1910. In connexion with these researches it is interesting to note that in 1900 Professor Osborn reached the conclusion that the common ancestors of the Proboscidea, Sirenia, and Hyracoidea would be found in Africa—a conclusion that was immediately afterwards confirmed by the discoveries of Dr. C. W. Andrews and Mr. H. J. L. Beadnell in the Egyptian Fayum.

In his long series of descriptive papers and memoirs Professor Osborn has dealt with almost all groups of mammals and reptiles, but special reference may be made to his important contributions to our knowledge of the Rhinoceroses, Horses, Titanotheres, and Dinosaurs. For the last fifteen years he has been occupied with a Monograph of the Titanotheres, which will shortly be published by the United States Geological Survey. For ten years he has also been accumulating notes for a similar Monograph of the Sauropodous

Dinosaurs. His most recent memoirs include those on the gigantic carnivorous Dinosaur *Tyrannosaurus* and on the integument of the Iguanodont Dinosaur *Trachodon*, both astonishing discoveries.

While engaged in descriptive work, Professor Osborn has always been keenly appreciative of its philosophical bearings, and he has published many dissertations on the transmission of acquired characters, mutations, adaptive variations, and allied subjects. In 1894 he contributed to the Columbia University Biological Series an important volume entitled *From the Greeks to Darwin*, which has been several times reprinted, and has also been translated into Italian. He discussed "Darwin and Palæontology" in the volume on *Fifty Years of Darwinism*, published by the Cambridge University Press in 1909. He stated the biological conclusions drawn from his study of the Titanotheres in a paper read before the National Academy of Sciences in 1911; and more recently he addressed the Paleontological Society of America on the "Origin of Single Characters as observed in Fossil and Living Animals and Plants".

Finally, Professor Osborn has made many valuable contributions to popular scientific literature, and among the latest may be mentioned his profusely and beautifully illustrated volume on the *Men of the Old Stone Age, their Environment, Life, and Art*, which was published at the end of 1915.

During the greater part of his career Professor Osborn has been much occupied with administration in varied ways. From 1892 to 1895 he was Dean of the Faculty of Pure Science in Columbia University. Since 1881 his organization, in connection with the American Museum, of a complete survey of the geological succession of the higher vertebrates in North America, has produced a flourishing school of vertebrate palæontology, represented by Earle, Matthew, Granger, Gidley, Loomis, Brown, Lull, Peterson, Gregory, and others. In 1896 he took a very active part in the foundation of the New York Zoological Park, under the auspices of the New York Zoological Society, of which he has been President since 1909. He is also a leading member of the New York Academy of Sciences, over which he presided in 1898–1900; and he has been a Trustee of the New York Public Library since 1912. Among other offices, he has held the Presidency of the American Morphological Society (1897), the Marine Biological Association (1898–1900), the Audubon Society (since 1910), and the American Bison Society (since 1914). Finally, in 1914, he became a member of the Belgian Relief Committee.

Professor Osborn has naturally received many honours both at home and abroad. He has been admitted to several university degrees already enumerated, and in 1914 he was awarded the Hayden Gold Medal by the Philadelphia Academy of Natural Sciences. He is a Foreign Member of the Linnean and Geological Societies of London, the Cambridge Philosophical Society, the Manchester Literary and Philosophical Society, and the British Association. From frequent visits, indeed, he is almost as well known to the scientific men of this country as to those of America, and his personal charm has won for him a large circle of devoted friends. Those who have visited him in his beautiful home amid the wooded heights at Garrisons-on-Hudson, have learned to appreciate the reasons for his success as a leader of men. He is a most unassuming student in the happiest circumstances, ever eager for the promotion of natural knowledge, and watchful to make the best use of all opportunities. To our tribute of admiration we would only add our best wishes for his continued enjoyment of health and strength long to carry on the work for which geological science is already so much indebted to him.

A. S. W.

II.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

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

(PLATE XIII.)

II. The Sunken Tubercles of *Discoides* and *Conulus*.

1. Introduction.

In 1914 I published, in this Magazine, an account of "Some Problematical Structures in the Holectypoida", indicating therein the presence of certain sunken features on the test-surface of "*Pygaster*" (*Plesiechinus*), *Coenholectypus*, and *Discoides*. Two series of depressions were described, of which one was wholly sutural in position, while the other was situated on the adoral ambulacral plates, and consisted of more or less sunken tubercles or granules. It is with the latter series of structures that the present paper deals. Although the title "problematical structures" remains appropriate, further work and more refined methods of preparation have made possible a more accurate description of them, and have considerably increased the area of their known distribution. Save for comparisons and passing references, the development of depressions on the tests of the Pygasteridæ and Holectypinæ will not be considered here. In Jurassic times, when these two groups were at their prime (in this country at least), sunken tubercles were in an incipient stage of evolution, and are in consequence very difficult to distinguish from their normal associates. It is therefore safer to deal first with the well-matured structures, as developed in Upper Cretaceous times. Moreover, the condition of preservation, and especially the character of the matrix, of Chalk fossils, make it easier to clean and stain the specimens without much risk of damage to delicate surface features. A test that has been naturally exposed by weathering is rarely serviceable for study of these structures, and more or less elaborate methods of staining and sectioning are necessary to render them sufficiently clear for accurate description. Small and inconspicuous as the depressions are, they nevertheless appear to have considerable phylogenetic and taxonomic importance. For their physiological value I have no suggestions to offer.

2. The Ornament of *Discoides cylindricus* (Lam.).

(a) *The Interambulacra of the Adapical Surface.*

An examination of an interambulacral plate midway between the apical system and the ambitus shows that the somewhat sparse and inconspicuous ornament consists of no less than five different types (see Pl. XIII, Figs. 1 and 2).

The primary tubercles are set in shallow areolæ, and are arranged serially in a definite pattern (see Hawkins, Geol. Mag., 1911, p. 448). They are few in number and cover but a small proportion of the surface of the plate. The secondary tubercles are very small, but are fairly numerous. They are areolate, but some of them seem not to possess mamelons. At times they form rough rings around the primary areolæ, and occasionally take on an irregularly linear arrangement in a transverse or radiating direction. The greater number of them seem to be quite fortuitous in position, and they vary considerably in diameter. Still more irregular, both in distribution and size, are the miliary granules, which are present in about the same numbers as the secondaries.

In addition to these three normal types of ornament, destined for the support of primary and secondary radioles and pedicellariæ, are two more of quite different appearance. One of these series of "tubercles" superficially resembles that of the secondary tubercles. The structures are of about the same size, but differ in the comparative scarcity of the special series, and in the character of their areolæ. They are either flush with the surface of the test (though readily visible owing to their extreme smoothness), or more commonly, slightly *raised* above the surrounding level. In the centres of these smooth circular areas are placed minute and inconspicuous mamelons, which seem to be always imperforate. The mamelons rise from pits of very little greater diameter than themselves, and do not project above the level of their "areolæ" (see Pl. XIII, Fig. 5).

The other aberrant series consists of tubercles which may be of any size from that of a secondary to almost that of a primary, having small mamelons on bosses set in areolæ which are deeply, but not entirely, sunk below the plate surface. When a test has been stained with a granular substance, this type of ornament becomes very obvious through the accumulation of colouring matter in the hollows. Although many of the sunken tubercles are situated without apparent order, some few seem to be fairly constant in position on the serial plates of a column.

The former series of peculiar "tubercles" will be more fully described in the section of the paper dealing with *Conulus*, in which genus similar structures are much more strongly developed, but the latter series (apparently absent from *Conulus*) requires more precise analysis.

Except that the mamelons of the "sunken tubercles" seem to be usually, if not always, imperforate, the chief difference between these structures and the normal primary tubercles lies in the character of their areolæ. There seems always to be some sort of a boss on which the mamelons are placed, though there is hardly any indication of its base. The floor of the areola is inclined, to make an angle with the plane of the test-surface, and the inclination is always adoral and inwards. In most cases the adapical border of the areola is sensibly raised above the surrounding level. Thus the axis of the tubercle (which is at right angles to the surface of the test in normal cases) slopes away from the apex downwards towards the ambitus (see Pl. XIII, Fig. 3). There seems to be almost perfect homogeneity among the sunken tubercles, apart from their variation in size.

On each of the first few plates from the apical system there is only one "sunken tubercle" (Fig. 1), constantly situated near the adoral transverse suture of the plate, and nearer to the interradial suture than the tubercle of the central (Cidaroid) series. This particular row of "sunken tubercles" can be distinguished, with but little variation in relative position, on all the interambulacral plates of the adapical surface except those immediately above the ambitus. Its members are commonly larger than the other less regularly disposed tubercles of the same type. The number of "sunken tubercles" on each plate shows a steady increase until just above the ambitus, but the depth of their areolæ shows a corresponding decrease. They never become very numerous. Although none of the additional "sunken tubercles" show any constancy of position comparable with that of the first-mentioned series, it is a general rule that the largest and most deeply excavate ones are situated near to, and sometimes in contact with, the adoral transverse margins of the plates.

A comparison of Figs. 1, 2, and 4 (Pl. XIII) discloses an interesting evolutional feature in connexion with the "sunken tubercles". In *Holectypus depressus* (the Cornbrash form, not that from the Inferior Oolite) there is one such tubercle on each of the interambulacral plates just above the ambitus, but never more than one. The plates near the apex are without any. This solitary "sunken tubercle" is in precisely the same relation to the central primary as it is in the adapical plates of *D. cylindricus*. Thus the "young" plates of the Cretaceous *Discoides* show the same development, in this respect, as the "adult" plates of the Jurassic *Holectypus*. The evidence for the phyletic continuity between the Holectypinæ and Discoidiinæ thus receives a convincing addition.

(b) *The Ambulacra of the Adapical Surface.*

The ornament of the ambulacral plates is on a smaller scale, and less thickly spread, than that of the interambulacrals, but it consists, none the less, of a corresponding series of five different structures. The primary tubercles are, on the whole, very regularly arranged in vertical series on every third plate. The secondary tubercles are few, and are usually associated with either a primary areola or a peripodium. The miliaries are very small, but are relatively numerous, and for the most part form transverse lines across the middle of each plate.

The two peculiar types of ornament are both present, the "raised secondaries" in fair numbers, and the "sunken tubercles" with much the same frequency for a given area as those of the interambulacra. I have never seen more than one "sunken tubercle" on an ambulacral plate. As in the interambulacra, there is one vertical series of these tubercles (situated near the peripodia) which tends to occur regularly on every third plate. As the figures show (Pl. XIII, Figs. 1 and 2), the regularity is not perfect, but in a whole column the series of tubercles has an average number one-third that of the plates. There are very few "sunken tubercles" apart from this series. All are identical in structure with those of the interambulacra.

(c) *The Interambulacra of the Adoral Surface.*

On the adoral surface, and at the ambitus, the ornament of the interambulacra suddenly becomes coarser and more abundant. The primary tubercles increase in size, numbers, and prominence, and especially in the excavation of their areolæ. Although their arrangement is on the same plan as that of the tubercles of the adapical surface, a series of secondaries becomes enlarged to form an additional transverse row towards the adapical margin of each ambital plate. This new series never reaches the size of the true primaries, but reproduces all the morphological features of that series on a slightly smaller scale. The normal secondaries are numerous, very uneven in size, and form very regular scrobicular circles around the primary areolæ, though many scattered ones also occur. The miliaries are few, so that much of the surface of the plates towards the peristome is quite smooth.

The "raised secondaries" maintain their numbers over the whole surface, but are proportionately smaller than those of the adapical region. Their "areolæ" seem to be more noticeably elevated above the average plate level, but their mamelons are still minute and lacking in prominence. I have failed to find any "sunken tubercles" below the ambitus on the interambulacra, and, in view of the remarkable freedom from ornament of the plates near the peristome, I feel fairly confident in stating that they do not occur there.

(d) *The Ambulacra of the Adoral Surface.*

The most striking difference between the ambulacra and interambulacra of the adoral surface, in the matter of ornament, lies in the development of unusually numerous secondary tubercles and miliaries in the former areas. Both of these sets of structures are far from numerous on the adapical parts of the ambulacra, so that the adoral parts of these areas are distinguished from all the rest of the test-surface by their abundantly granular character. In scale this ornament is perhaps a little finer than that of the adjoining interambulacra.

The "raised secondaries" are present, though far from abundant, and are precisely similar to those on the adoral interambulacral plates. But, in contrast with the latter areas, "sunken tubercles" occur in addition. They are, however, very small, and seem to belong exclusively to the regular series of the adapical surface. They are restricted to the immediate neighbourhood of the "poriferous zones", and are placed with fair regularity on the perradiad side of every third peripodium. The plates on which they occur are, in the majority of cases, demi-plates. I have been unable to locate them with certainty on the plates at the ambitus, but these are so small and so congested with granular ornament that their absence from that region is probably more apparent than real. Their general proportions and distribution are accurately shown in Pl. I, Fig. 3, of Geol. Mag., Dec. VI, Vol. I, 1914. It is noteworthy that the obliquity of their axes is exactly opposite to that of the adapical tubercles, the areolæ being inclined towards the ambitus in each case.

(e) *The Homology of the "Sunken Tubercles" of Discoides and the "Glassy Tubercles" of Echinoneus.*

The "sunken tubercles" of *D. cylindricus* are found over the whole coronal surface of the test except near the apex and on the interambulacra of the adoral surface. Their distribution on the plates seems to indicate that they are not fundamentally special structures but are modified examples of the secondary tubercles. As far as can be ascertained, the areolæ of the "sunken tubercles" are generally raised above the surrounding level on the side away from the ambitus, and are sunk more or less deeply below it on the opposite side. The greater part of each areola is depressed, and the sunken part is deeper than the raised part is high. Thus their mamelons, and whatever articulated projections that may have fitted on to them, are inclined towards the ambitus. These structures occur in *Plesiechinus*, *Pygaster*, *Holectypus*, and *Coenholectypus* as well as in *Discoides*, but, as far as my present observations have indicated, reach their maximum development, at least as regards numbers, in the last-named genus. They seem not to occur in *Conulus*. The material at present available for a study of *Pyrina* is inadequate, but I believe that they do occur in *P. desmoulinsi*, though in that species they seem to be wholly sunken, with an axis once more at right angles to the surface of the test. I have not seen any comparable structures in any other Mesozoic genera.

There are two sets of structures found in Tertiary and Recent forms with which comparison is possible. Many of the more specialized Spatangoids, such as *Lovenia* and *Eupatagus*, have a few large tubercles on the interambulacra of the adapical surface. These are set in very deeply sunken areolæ, and are usually oblique in relation to the test-surface. But two equally important features in the Spatangoid tubercles are in direct contrast with those of *Discoides* and its allies. The sunken tubercles of the recent forms are always primaries, in point of size, while those of *Discoides* are always smaller than the main tubercles; and the sunken character of the Spatangid areolæ seems to be due to the development of secondary thickening on the rest of the plates, and its absence from them, while the actual elevation of part of the areolæ in *Discoides* shows that such a growth has played no part in their production.

The other series of sunken tubercles with which comparison can be made is found in *Echinoneus* and *Micropetalon*. There can be little doubt that, from a phylogenetic standpoint, these genera are much more nearly related to the Holectypoida than are the true Spatangids, although it seems equally certain that they are not directly descended from *Discoides*. Scattered more or less promiscuously over the plates of both areas in *Echinoneus* are the small depressed structures known as "glassy tubercles". Their structure and distribution are admirably figured by Westergren (Mem. Mus. Comp. Zool., Harvard, 1911). These glassy tubercles are roughly similar to the secondaries in size, but are distinguished from them by their deeply sunken areolæ and small "mamelons". Whatever the glassy tubercles may be, either in origin or function, their general facies is so extraordinarily like that of the "sunken tubercles" of *Discoides* that it is almost impossible to doubt the homology of the two structures. I have not noticed any specially vitreous appearance in the mamelons of the "sunken tubercles" of *Discoides*, but this might be due to fossilization or the imperfect development of the structures in Cretaceous times. If, as I believe, corresponding structures occur in *Pyrina*, which is very nearly allied to *Echinoneus* in all essential features, and almost certainly ancestral to it, the correlation of the two sets of ornament would be rendered more certain. Their absence from *Conulus* would indicate that that genus, though resembling *Pyrina* in many features, has diverged along a line of evolution leading to some other goal than *Echinoneus*, and one in which "glassy" or "sunken" tubercles are not developed. For the present it is enough to definitely state the opinion that the "sunken tubercles" of most Holectypoids are the forerunners of the glassy tubercles of *Echinoneus*.

3. The Spiniferous Pits of *Conulus albogalerus*, Leske.

(a) *Description of the Pits.*

This familiar and common species from the higher zones of the Upper Chalk may present very different surface features under varying conditions of preservation and preparation. Ordinarily the surface of the test is almost smooth on the adapical surface, owing to the faint relief and shallow areolæ of the primary tubercles, and the small size of the secondaries and miliaries. But most specimens that have been freed from their adherent matrix by gentle methods show, in contrast, a strongly shagreened character, which is caused by the projection of very numerous rounded prominences of considerable elevation but small diameter. These prominences are readily detached from the plates by too vigorous brushing, and seem to separate from them after a very slight degree of weathering; and they as often as not are removed with the matrix if this is broken off by a blow. That they commonly remain in position on tests which have been entirely denuded of radioles and pedicellariæ indicates that these prominences are not appendages of that type, but their frequent and easy separation from the plates with which they articulate proves that they are not tubercles. They seem to occur in almost the same numbers in *C. rhotomagensis* and *C. subrotundus* as in *C. albogalerus*, but owing to the toughness of the matrix in which the two former species are embedded, they are only exceptionally seen in situ.

The earliest description of the prominences scattered over the test of *C. albogalerus* is that given by Forbes (Mem. Geol. Surv., dec. III, pl. viii) in 1850, and no later accounts of them seem to add much to his statements and figures. The following are the sections of his discussion of "*Galerites*" *albogalerus* which bear upon the subject. "The miliary tubercles of the dorsal plates bear very minute and short tubercular smooth spines, each standing apart from its neighbours. . . . [On the adoral surface] curious club-tipped pedicellaria-like bodies occur among [the normal radioles], which may represent the spines of the miliary tubercles described as occurring on the dorsal surface. . . . The minute moniliform spines of *G. albogalerus* are $\frac{1}{133}$ of an inch in length and of equal diameter. Three were measured, and all were as nearly as possible of the same size and proportions. They were all perfectly smooth." On pl. viii, fig. 8 are given two "greatly magnified figures of the small tubercular spines of the dorso-lateral plates". The spines figured are nipple-shaped, with smooth domes and splayed proximal margins. The description is incorrect in one particular, for these prominences do *not* occur on the miliary granules, nor yet on the secondary tubercles, but in association with small pits which are not indicated on Forbes' somewhat imaginative fig. 5. I am unable to confirm the presence of the "pedicellaria-like" structures on the adoral surface, but they may be attached by soft tissues only, and so only preserved when the ordinary radioles are in place. Otherwise, save for the correction made above, the description and figures seem thoroughly accurate, though by no means complete.

The study of such minute structures in a fossil is necessarily attended with great difficulty, and the observations made in one case need abundant and frequent comparison with separate investigations on numerous specimens. Fortunately, the prominences are so thickly scattered over the test, and examples of the species showing them in place are so common, that sufficient material for confirmatory analysis has been readily available. I have found that the most satisfactory process for a study of the surface details of *Conulus*, and indeed of most fossil irregular Echinoids, is to wash them over with Indian ink much diluted with water. This reagent leaves a very fine black deposit in all the small depressions of the test (such as plate-sutures and podial pores); and, if the surplus be rubbed off with a damp cloth before it has quite dried, only such depressions retain the stain. A brush must not be used for the removal of the ink, for it scours out the depressions irregularly, and produces disconcerting results. It must be borne in mind that a specimen so treated cannot be cleaned after the ink has once dried, so that valuable or borrowed specimens must be examined in their natural state.

Pl. XIII, Fig. 8, shows the general appearance of a series of coronal plates midway between the apical system and the ambitus in a specimen of *C. albogalerus* from the base of the *Uintacrinus* subzone of Shaw, near Newbury. All the projecting prominences have been removed by rubbing with a stiff brush, but none of the miliaries or tubercles have suffered in the process. The drawing shows all the external ornament of the plates, correct in position and proportions. To avoid perspective, the interambulacral plates have been projected up to the plane of the ambulacrum which they flank, the outlines having been traced from three separate photographs. It will be seen that there are four types of ornament. The main tubercles, with broad bosses, crenulated parapets (omitted in the figure), and small mamelons, are set in areolæ which extend very little beyond them, and are arranged in an "hour-glass" plan on the interambulacral, and with some regularity on the ambulacral, plates. Abundantly scattered among these large tubercles, and roughly encircling them, are small secondaries, similarly set in areolæ, but without defined mamelons and imperforate. These vary slightly in size, but are remarkably uniform in character. Here and there simple granules appear, without areolæ; sometimes these are nearly as large and prominent as the secondaries, but usually they are very small. The fourth type is altogether different, and is somewhat diagrammatically shown in Fig. 8, but an enlarged view (Fig. 6) makes its characters clear. It consists of a series of pits of minute but very constant size, encircled by faintly raised and ill-defined smooth areas. These surrounding platforms are usually of about the same diameter as the areolæ of the secondary tubercles, but are rarely quite circular, and never so distinct as either of the figures suggests. Each of the structures might be compared to a shallow well with a broad but low parapet. The encircled pits are present in about the same numbers as are the secondary tubercles, and, like them, may enter into the scrobicular rings of the primaries, although the majority are scattered without apparent order. None of the coronal plates of the adapical surface, however small, is without them, and in the ambulacra they may be found near or even in contact with the peripodia. It is from these encircled pits that the small nipple-shaped "spines" project in unworn specimens.

One of the pits is shown, in plan and section, on Pl. XIII, Fig. 6. The pit is seen to be a roughly hemispherical concavity, comparable with the *negative* of a mamelon. The encircling platform may similarly be compared to a negative areola.

As far as can be ascertained, the encircled pits occur in varying numbers on all the coronal plates of the adapical surface of *C. albogalerus*. They are few and sparse on the young plates near the apical system, and increase in number (with no corresponding change in size) towards the ambitus, but I can find no trace of them on the adoral surface. The plates there are much more coarsely and closely granulate; and, if the structures under consideration do exist below the ambitus, they would seem to have become prominent instead of re-entrant. No pits occur on the plates of the apical system.

The "spines" which spring from the encircled pits are remarkably uniform in size and character over the whole adapical surface. Their appearance when viewed in situ is precisely like that of the figures given by Forbes (loc. cit., fig. 8). That author's remark that "they are all perfectly smooth" is, if anything, an understatement. The entire exposed surface of each "spine" is extraordinarily glossy, outshining even the primary mamelons in polish. When it is remembered that the radioles of this species have fluted, and even fringed, shafts, and crenulated collars, the contrast between them and the "spines" of the encircled pits is manifest. After many failures, I have succeeded in examining the articulating surface of the "spines", both in solid and sectional view. They show an interesting, but not surprising, character. The greater part of the area of the "surface of attachment" is quite smooth and flat, and the whole surface is of considerably greater diameter than the top (or distal end) of the "spine" owing to the splaying out of the lower part of the "shaft". In the middle of the somewhat irregular circle of this surface there appears a roughly hemispherical knob, slightly but distinctly projecting beyond the general plane (see Pl. XIII, Fig. 7). This knob is almost exactly of the same diameter as a pit, into which it fits after the manner of the sutural knobs and sockets of *Arbacia*. The smooth part of the lower surface of the "spines" seems to correspond fairly accurately with the size and shape of the raised parapets (or "negative areolæ") around the pits. Such a mode of articulation would allow of very limited movement; indeed, the only opportunity would be for rotation of the "spine" about its long axis. There is no trace of muscular attachments, nor of perforation for a ligament, either on the plate or on the "spine", but the former, at least, may well have existed on the "negative areolæ" as they do on the normal ones. There is no indication of any syzygial union between the "spine" and its pit.

It seems, therefore, that an "encircled pit" represents a modified secondary tubercle, whose mamelon and boss have become re-entrant instead of projecting, supporting a glossy and short "spine" whose acetabulum is convex instead of concave, and whose collar is expanded to rest in contact with the raised areola. Whether the "spine" is merely the proximal part of some such appendage as a pedicellaria or not, cannot be determined. The surprising polish of its entire outer surface would imply that, if any prolongation of the structure existed, a region of soft, flexible tissue intervened between that and the distal end of the "spine".

(b) *Comparison with the Structures of D. cylindricus.*

The peculiar secondary tubercles of *Discoides* (referred to above) are the only structures with which comparison is possible. Nothing in the least like the "spiniferous pits" of *C. albogalerus* occurs, as far as I am aware, in any other Echinoid, fossil or recent, excepting the other species of the genus. In *C. subrotundus* and *C. rhotomagensis* they are present in similar numbers, and of the same character, as in the Upper Chalk species; so that they may be regarded as a generic, or possibly a family, peculiarity.

The specialized secondaries of *D. cylindricus* resemble the "pits" of *Conulus* in many important respects. They are definitely secondary tubercles in point of size and distribution, sharing with them in the construction of the scrobicular circles. They have areolæ which are usually raised above the surrounding level of the test, and which are never sunken like those of the normal tubercles (see Pl. XIII, Fig. 5). The mamelons are, it is true, convex, but they are unusually small, and are set in a deep excavation above whose rim they do not appreciably project. There is every reason to believe that these mamelons supported small "spines", but these would, owing to the exposed nature of their articulation, naturally become detached by the same processes that remove the normal

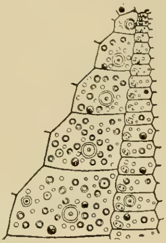


FIG. 1.

FIG. 2.

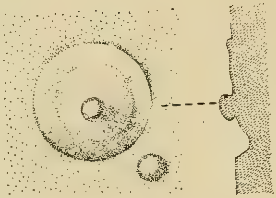


FIG. 3.

FIG. 4.

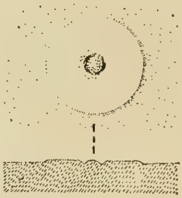


FIG. 5.

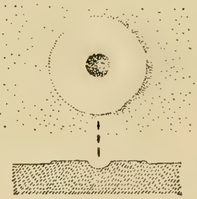


FIG. 6.

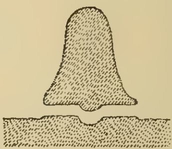
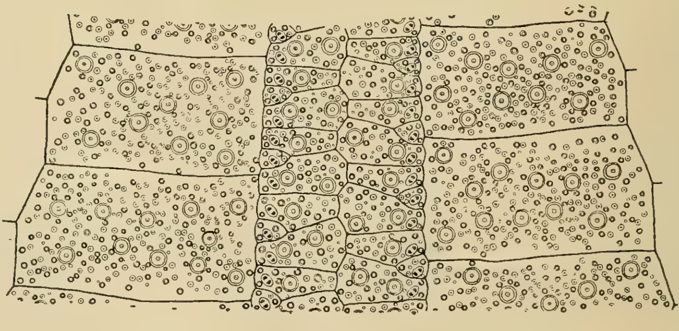


FIG. 7.



H. L. H. del. FIG. 8.

SURFACE FEATURES OF *DISCOIDES* AND *CONULUS*.

radioles. Thus the only serious difference that exists between these peculiar secondaries and the "pits" of *Conulus* is the presence of convex mamelons; but these are far less prominent than the normal ones of the same specimens. It may be fairly confidently suggested that the specialized secondaries of *Discoides* show an early stage in the evolution of the "pits" of *Conulus*, the areolæ having already risen, but the tubercles being only partly reduced. The apparent absence of the "sunken tubercles" of *Discoides* from the species of *Conulus*, and the almost certain absence of "encircled pits" from *Pyrina*, invite speculation as to the relationships of these three genera into which it would be premature to enter in this paper. It is sufficient for the present purpose to point out that, as regards these curious surface features, *Discoides* possesses both types, one of which occurs in *Pyrina* and the other in *Conulus*, two genera that are far in advance of *Discoides* on the path of true "Irregularity".

4. Summary.

Two sets of specialized tubercles are described, "sunken tubercles" and "negative secondaries". Both types occur in *Discoides cylindricus*, but the former type only is fully developed there. These "sunken tubercles" are believed to occur in *Pyrina* also, and are further correlated with the "glassy tubercles" of *Echinoneus*. They also occur in the earlier Holectypoida. The "negative secondaries" are found in their fullest specialization in *Conulus*, and there support the short, closely articulated, glossy "spines" that are familiar to all collectors who work in the Upper Chalk. There is thus an indication that there may be two distinct lines of descent from *Discoides* (omitting the obvious sequence to the Clypeastroids), in one of which the changes led to the recent *Echinoneus* through *Pyrina*, while in the other *Conulus* marks the first stage. No suggestion as to the physiological value of the two series of structures can be advanced.

EXPLANATION OF PLATE XIII.

Fig.		
1.	*Discoides cylindricus.*	Adapical portion of corona. × 5.
2.	,, ,,	Plates midway between apex and ambitus. × 5.
3.	,, ,,	A sunken tubercle in plan and section. × *c.* 30.
4.	*Holectypus depressus.*	Interambulacral plate midway between apex and ambitus (No. 17 from the ocular). × 5.
5.	*Discoides cylindricus.*	"Negative secondary" in plan and section. × *c.* 30.
6.	*Conulus albogalerus.*	"Encircled pit" in plan and section. × *c.* 30.
7.	,, ,,	Diagram of articulation of "spine" with pit. × *c.* 30.
8.	,, ,,	Plates midway between apex and ambitus (amb. III). × 5.

In figs. 1, 2, 4, and 8 the several types of plate-ornament are in their correct positions and proportions, but are represented by somewhat conventionalized patterns. The outlines of the figures are based on tracings from photographs as well as on actual measured drawings so as to ensure accuracy.

III.—The Base in the Camerate Monocyclic Crinoids.

By F. A. Bather, D.Sc., F.R.S., F.G.S.

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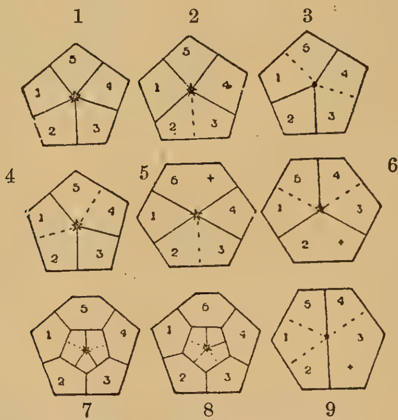
In "The North American Crinoidea Camerata", 1897, Wachsmuth & Springer discussed at length the various modes of partitioning the base, and attempted to give a morphological, if not a physiological, interpretation of the various appearances. In reviewing this part of their work (Geol. Mag., Sept. 1898, pp. 426–428) I contented myself with giving a summary of their views, corrected only in so far as facts of structure were concerned. This summary was reprinted in the Echinoderm volume of Lankester's *Treatise on Zoology* (1900, pp. 122, 123), although some of the theory involved in it was not in accord with the phylogenetic hypotheses expressed or implied in the taxonomic part of that work. Mr. Herrick E. Wilson[1] has been more critical. He has brought Wachsmuth & Springer's interpretations to the bar of logic, of fact, and of physiological theory, and has found it necessary to replace most of them by a fresh series.



Figs. 1–9.—Diagrams summarising the views of Wachsmuth & Springer on the structure of the Crinoid base. The posterior basal is numbered 5. The region where addition is supposed to have taken place is marked +.

Reference to Table A in Wachsmuth & Springer's monograph, or to Fig. 4 in my Review (here reproduced as Figs. 1 to 9), will show an area of the base marked x or + and believed by the American authors to represent the portion that was added to one or other basal so that it should fill out the space required. Mr. Wilson fails to understand what stimulus could have initiated this hypertrophy now in one place now in another; and, since the introduction of such a wedge involves torsion of the rest of the basal circlet, he seeks in vain for physiological processes that could bring this about or

[1] "Evolution of the basal plates in monocyclic Crinoidea Camerata": *Journ. Geol.*, xxiv, pp. 488–510; 534–53; 666–84, pls. i–iii. August to November, 1916.

processes of growth that could even permit it. Had Mr. Wilson not been in communication with Mr. Springer, I should have said that he had taken Wachsmuth & Springer's diagrams more seriously than those authors ever intended, and that his criticism was more laboured than the case demanded. At any rate he has swept the field clear, and his own conclusions may be discussed on their merits. They are:—

"1. The ancestor of the monocyclic Camerata was a simple, generalized crinoid with pentamerous symmetry."

If "generalized" means "Inadunate", then this supports the suggestion that I have more than once opposed to the views first of Wachsmuth & Springer and later of Professor Jaekel.

"2. The base of the pentagonal Camerata is not the result of reversion from an intermediate hexagonal stage, but is in a primitive condition as far as influence of the anal plate is concerned."

The sting in this seemingly obvious statement is the corollary that the quadripartite base of the Melocrinidae (Fig. 2) cannot be derived from that of such a form as *Xenocrinus* (Fig. 5). Such a derivation is one of the views above alluded to as inconsistent with my taxonomy. I have therefore no qualms in accepting Mr. Wilson's conclusion.

"3. The anal plate is of secondary origin, and originated by primary interpolation between the latero-distal margins of the posterior radials."

It is cheering to note Mr. Wilson's dismissal of the view that the anal x is a supplementary plate, suddenly introduced, and his clear exposition of its origin from some plate lying above the radials, which plate gradually grew downwards at its lower margin and became resorbed at its upper margin, without any disturbance of adjacent plates (see Geol. Mag. 1899, pp. 40 & 44), and I welcome the extension of this theory to the Camerata.

"4. The hexagonal base of the monocyclic Camerata [our Figs. 5, 6 & 9] resulted from the separation of the posterior radials and trunkation of the posterior basal by the anal plate, the anal plate having been interpolated by portional migration in the space created by the demand of the hind-gut for enlargement."

This is a consequence of conclusion No. 3, and is a restatement of Beyrich's sentence (1871, p. 51): "Da das Hexagon nur dadurch entsteht, dass zwei Radien durch ein Interradialfeld bis zur Basis herab auseinandergeschoben werden. . . ."

"5. The widening of the posterior basal upon interpolation of the anal plate was bilaterally symmetrical."

This is not merely a statement of result, comparable to the conclusion of Beyrich's sentence: "so erhält das Hexagon für des Krinoid die Bedeutung eines symmetrischen Hexagons, u.s.w.," but it means that the posterior basal expanded equally on either side of the axis of symmetry, and not merely on its right side. In 1898 I pointed out that, as a statement of result even, this did not apply to all crinoids, but probably Mr. Wilson intends to refer only to Monocyclic Camerata. In them it can apply only to the hexagonal quinquepartite base, as in *Tanaocrinus*, or quadripartite, as in Xenocrinidae (Figs. 1, 5). For such bases it is the most simple explanation; but, since the pressure of the hind-gut was presumably along the right posterior suture, one must admit the possibility of this having pushed the posterior basal over to the left and necessitated growth on its right side. This, as Mr. Wilson says (p. 669), is "a question of directive controls which cannot be readily answered". I prefer, therefore, to leave the door open.

> "6. The quadripartite, hexagonal base [our Fig. 5] resulted from the anchylosis of the anterior pair of basals in a hexagonal genus with a pentapartite base."

Translated into phylogeny, this means that Mr. Wilson follows Mr. Springer (1913) in accepting my derivation of Xenocrinidae from *Tanaocrinus* (1898, 1900).

> "7. The posteriorly directed basal suture in the subequally, tripartite and bipartite, hexagonal bases [our Figs. 1, 6 & 9] is the homologue of the right-posterior basal suture in the pentapartite and quadripartite bases, which has shifted its position through atrophy of the right half of the posterior basal and a compensating hypertrophy of the left side of the right-posterior basal."

The quadripartite base (hexagonal or pentagonal) always tends towards symmetry in itself and in relation to the sagittal axis (radial axis of Beyrich), so long as it remains quadripartite; but any fusion of its elements throws it out of symmetry with the sagittal axis, and to regain the relation a shifting of one or more sutures is required. Mr. Wilson argues that the fusion is of the posterior basal with the one on its left, and from this his conclusion 7 naturally flows. The evidence he adduces from an abnormal *Steganocrinus pentagonus* shows that the posterior basal could, on occasion, fuse with the one on its right. All the same his conclusion is to be accepted, not so much for the reasons he gives, as for the more general one that the right posterior suture is on the line of weakness or fluidity, due to intestinal pressure. The exception in the single *Steganocrinus* just mentioned was facilitated by its strongly marked radial pentamerism and by the relative smallness and solidarity of its base.

> "8. The basal sutures lost through anchylosis are potentially present in the basal cup, and liable to reappear in individual cases of delayed anchylosis, but not as a phylogenetic character."

That is to say, there is no reversal of evolution.

> "9. The tripartite, hexagonal base in the Batocrinidae resulted from the appearance of the posteriorly directed basal suture (see 7) in a quadripartite base, accompanied by closure of the anterior and left-posterior basal sutures."

This differs from Wachsmuth & Springer's interpretation (our Fig. 6) by the fusion of plate 3 with 2 instead of with plate 4; but it is not quite clear, for in a quadripartite base, on Mr. Wilson's own hypothesis, the anterior suture is the one already closed (as in our Fig. 5). All that happened was the fusion of the posterior and left posterior basals (Nos. 5 and 1 in the figure) and the shifting of the right posterior suture as under 7. If this be Mr. Wilson's meaning, he is mistaken in thinking that I do not agree with it; but to his criticism of my supposed views I shall return later.

> "10. The hexagonal, tripartite base of the Hexacrinidae resulted from the interpolation of an anal plate by portional migration, through shifting of the right-posterior basal suture to a posterior position, and closure of the anterior and left-posterior basal sutures, in a simple platycrinid with a pentapartite base."

> "11. The bipartite, hexagonal base in the Hexacrinidae resulted from interpolation of the anal plate by portional migration, shifting of the right-posterior basal suture to a posterior position, and closure of the right-anterior basal suture, in a platycrinid with a pentagonal, unequally tripartite base."

["right-anterior" seems to be a misprint for "left-anterior".]

These two conclusions, apart and in conjunction, form the most novel part of Mr. Wilson's paper, and he has made out a fair if not absolutely convincing case. Wachsmuth & Springer thought that the tripartite *Hexacrinus* base (Fig. 6) was derived from a tripartite base of *Platycrinus* type (Fig. 3) by intercalation of the anal, swinging round of the right posterior suture to the sagittal axis, as in Batocrinidae, and widening of the left anterior basal (numbered 2). Mr. Wilson calls this a "torsion theory", and objects to an enlargement elsewhere than adjoining the right posterior suture; or, discussing an alternative hypothesis [where his meaning is perhaps obscured by another misprint] he says the theory "demands the reappearance" in Hexacrinidae "of the right-anterior basal suture" lost in Platycrinidae. Perhaps Mr. Wilson, here as elsewhere, does not attach enough importance to the general symmetry imposed by mechanical stresses, or to the selection-value of a stronger disposition of sutures. If, as he concedes, it was possible for the right posterior suture to shift 72° under certain stimuli, why should it be so impossible for the anterior suture to shift an equal amount under other stimuli? Mr. Wilson, however, prefers to derive his Hexacrinid base from the quinquepartite base of a primitive Platycrinid (Fig. 1), and to imagine it as composed of posterior (5) and left posterior (1) basals fused, left (2) and right anterior (3) fused, and right posterior (4) enlarged. He is entitled to his hypothesis, but it is still open to the objection which I raised in 1900, that no Silurian form is known which could link the imaginary 5-basalled Platycrinid with the Devonian Hexacrinid.

The bipartite base of *Dichocrinus* and other Hexacrinidae (Fig. 9) was regarded by Wachsmuth & Springer as derived from the tripartite Hexacrinid base (Fig. 6) by the fusion of the compound plate on the left (5 + 1) with the small (left anterior) basal (2), and by the shifting of the anterior suture back again into the sagittal plane. This seemed plain sailing, but Mr. Wilson again objects that "the pressure from the growing hind-gut . . . cannot affect the anterior basal sutures". Granted; but, as before, why overlook the mechanical stimuli? "Furthermore, the examples of [abnormal] suture reappearance in the bipartite base show the potential presence and position of all but the right-posterior suture." One of these examples (Wilson's plate vii, fig. 10) shows left posterior, anterior, and right anterior sutures, which last does not accord with the enlargement of the right anterior basal (3 +) imagined by Wachsmuth & Springer. The two other examples show a suture in the anal interradius, and why the hypothesis demands that this should have been shifted back to the right posterior radius I do not understand. Mr. Wilson also objects, as before, that the anterior basal suture "lost through anchylosis" cannot reappear. But it is only Mr. Wilson who has supposed that suture to be lost; Wachsmuth & Springer thought it was shifted; and to claim that it could not shift back is to ride "the irreversibility of evolution" a little too hard. Perhaps Mr. Wilson is bothered by Wachsmuth & Springer's added element x, but, as already said, I think he attaches too much importance to a diagrammatic mode of expression. However, let us look at his own interpretation (having first corrected another unfortunate misprint). He derives the *Dichocrinus* base (Fig. 9) from one of Platycrinid plan (Fig. 2), by fusion of the left compound basal (5 + 1) with the small (left anterior) basal (2), accompanied by a shifting of the right posterior suture into the anal interradius, in line with the unmoved anterior suture. Granted the antecedent conditions, this is certainly a simpler explanation, though Mr. Wilson does not say how he reconciles it with his own views as to the right posterior suture in abnormal individuals. In choosing between the two interpretations we must be guided by the phylogeny, and here Mr. Wilson claims that the earlier examples of *Dichocrinus* have a flexible tegmen more readily to be derived from that of an early Platycrinid than from the "ridged tegmen" [?"rigid"] of *Hexacrinus*. This seems a fair argument, and in this case plenty of Silurian and Devonian genera are known that could be thus linked up with *Dichocrinus*. If Mr. Wilson's interpretation of *Dichocrinus* be accepted, then, whatever be the interpretation of *Hexacrinus*, it will follow that the two genera evolved along independent lines.

Such are the main theses of this interesting paper; but there are subsidiary matters that call for comment.

In saying that Wachsmuth & Springer are the only writers who have undertaken a general treatment of the subject, Mr. Wilson is hardly fair to H. E. Beyrich, whose well-known paper "Ueber die Basis der Crinoidea brachiata"[1] finds no place in his "Bibliography". If Mr. Wilson has not studied that paper he has not been fair to himself either. Allusion has already been made to some of its broader conceptions, here overlooked; and, to descend to a detail, Mr. Wilson would have learned from it that the plan of base which he has discovered in some specimens of *Melocrinus* from Missouri, was described by Beyrich as normal for *M. hieroglyphicus*.

In his account of plate-growth (pp. 501, 502) Mr. Wilson suddenly breaks away from sentences with a strangely familiar ring to state that the plates, after they have come into contact, increase in size

[1] *Monatsber. Akad. Wiss. Berlin*, February, 1871, pp. 33–55.

"by interstitial growth" (p. 502, also p. 497). The phrase is taken from Wyville Thomson's account of the development of *Antedon* (1865). Whether Wyville Thomson used the phrase (which he qualified by "apparently") in its customary meaning or no, there is no support for the idea. It might, if true, have been useful in explaining the changes in the basal plates, but Mr. Wilson makes no further use of it.

Mr. Wilson is strongly disinclined to believe that division of plates has ever occurred as a process of normal development in Echinoderms. Indeed, he stoutly affirms "that there are no known instances of the bisection of a growing plate in modern Echinodermata" (p. 674). This is a question of deep morphological importance. Presumably Mr. Wilson has not made his assertion without ransacking the literature; and yet one would like to hear what the embryologists have to say.

In discussing possible methods of plate migration, Mr. Wilson says (p. 539, I quote from a copy corrected by him): "in *Antedon* . . *Promac*[h]*ocrinus* and *Hathrometra* . . . the anal and radianal, being more firmly attached to the viscera than to the adjacent plates, are bodily lifted out of the cup into the tegmen by the accelerated growth of the hind-gut. This process is the one which undoubtedly explains the migration of the radianal in all fossil crinoids." This explanation may perhaps be correct for the recent crinoids mentioned, and it may perhaps apply to the later evolutionary stages in the Dendrocrinoidea (Poteriocrinidae *s. lat.*); but to say that it is "the one" explanation for "all fossil crinoids" overshoots the mark. In the first place the observed ontogeny of the comatulids cited is too rashly applied to the supposed phylogeny of various extinct genera in which there is no actual proof of migration during individual growth. After all, the view has been held that the ontogenetic changes in the comatulids are a recapitulation of previous phylogenesis (Bather, 1893, Recapitulation Theory in Palæontology. *Nat. Science*, II, p. 275, also III, p. 238). The plates of the cup are not really "attached to the viscera", but lie in the integument. It is true that in the larval *Antedon* the anal is not closely apposed to the adjacent cup-plates; but in palaeozoic crinoids there was a well-formed sutural union. The growth of the hind-gut was no doubt the stimulus, but its action can hardly have been a direct pull. The anal area first widened to give it room, and the space was filled partly by a *downward* growth of some plate above, partly by widening of the adjacent radials and the posterior basal, partly by portional migration (to adopt Mr. Wilson's useful phrase) of that plate below the right posterior radial which we call the radianal, sometimes even by development of a supplementary plate below the radianal (e.g. *Carabocrinus*). In these cases the expansion of the radianal was in an adanal direction, but usually along a horizontal line, sometimes even downwards into the basal circlet (e.g. *Carabocrinus*, *Strophocrinus*, and *Thenarocrinus*, all overlooked by Mr. Wilson); it was no more dragged up than was the upper anal dragged down. Sometimes the widening of the cup was effected in a different manner; in the Pisocrinidae and Catillocrinidae, for instance, the radianal has enlarged on the right side of the right posterior radial—it has grown away from the anal interradius. To this Mr. Wilson's explanation cannot apply. I entirely agree with his emphasis on the pressure exerted by the hind-gut (p. 545); but while I admit "push" and "shove", I reject "lift" and "pull".

In discussing the evolution of the Batocrinoidea (p. 671) Mr. Wilson seems to have misunderstood some remarks in the Echinoderm volume of Lankester's "Zoology" (1900, pp. 165, 166), since he writes "Bather, in accepting this theory [Wachsmuth & Springer's derivation of the tripartite hexagonal base from one of Platycrinid plan] apparently assumes an intermediate step, for in the generic discussion of *Abacocrinus* he says: 'From the imagined intermediate step (not from *Abacocrinus* itself) *Periechocrinus* may have been derived by fusion of 2 BB.'" The quotation is inaccurate, and the interpretation of it wrong. A few lines back I had written: "Between it [the Silurian *Abacocr.*] and [the Ordovician] *Compsocrinus* we must imagine a form in which the free Br became biserial, while the free rami forked several times"; and I continued: "From the imagined intermediate form . . . *Periechocrinus* may have been derived by fusion of 2 BB." The intermediate form of course resembled *Compsocrinus* and *Abacocrinus* in having 4 basals, with the posterior basal truncate and supporting an anal. Also, since *Periechocrinus* has 3 basals, if these were derived "by fusion of 2 BB", its ancestor must have had 4 basals. Therefore I neither "accepted" nor "emended" the theory of Wachsmuth & Springer, but my working hypothesis was the one which Mr. Wilson has himself supported with such wealth of argument.

It is delightful to find a new worker ready not only to ask a heap of inconvenient questions, but to work out the answers to them. I trust that this article has done justice to his suggestive paper. But whether the fault be the author's, or his printer's, or his reviewer's, it is to be feared that the attempt at elucidation has led me yet again into what a good-natured critic once described as my unforgiveable "habit of offering up his own interpretations of what he does not thoroughly understand in the works of other authors". If the account does not tally with Mr. Wilson's intentions, I hope he will forgive me all the same.

IV.—*Poikilosakos*, a remarkable New Genus of Brachiopods from the Upper Coal-measures of Texas.

By D. M. S. Watson, M.Sc., Lecturer in Vertebrate Palæontology, University College, University of London.

(PLATE XIV.)

INCLUDED in a large series of marine fossils which I collected from the Cisco Beds of Uralian or Upper Coal-measure age at a well-known locality on the west bank of the Salt Creek at Graham, Young Co., Texas, are several fragments of a single very large nautiloid shell. These fragments had lain so long on the sea-floor before they were covered by mud that they have in many cases been much eaten into by sponges and worms, and are covered by adherent organisms, mostly Bryozoa. Attached to them, however, are twenty specimens of the remarkable Brachiopod which forms the subject of this paper. These specimens are in general perfectly preserved, and are easily freed from their surrounding clay by washing with a tooth-brush.

All the specimens preserved are ventral valves. Each is adherent by the whole of its external surface usually to the outer, but sometimes to the visceral surface of the nautilus shell, or even to an adherent Stromatoporoid. Where an individual has been fixed on a flat surface and has had so much free space round it that it could grow freely, it forms an almost circular area whose margins are exceedingly thin and tightly adherent to the base. On rough surfaces and where two individuals have met and interfered with one another the general form may be very irregular. The largest individual I have measures 2·4 × 1·7 cm., the smallest ·75 × ·65 cm.

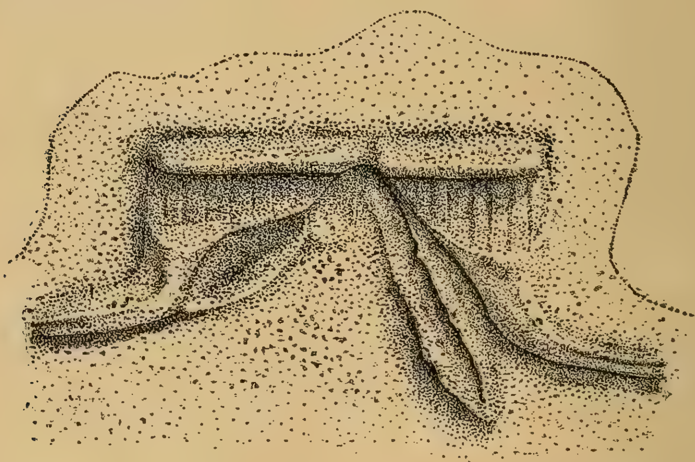
The hinge-line is straight and very short, in adults one-sixth the width of the shell. It is a very distinct groove whose posterior side is formed by a ridge standing up from the shell. The posterior surface of this ridge falls rapidly to an expansion of the valve which is usually of small extent, and in the smallest individual is nearly absent. The posterior surface of this ridge is the area, so reduced as to be almost unrecognizable. The delthyrium is represented by an extremely shallow notch in the middle of the hinge-ridge, which is invariably present though difficult to see. There is no trace of a deltidium either true or false.

On the anterior side of the hinge-line and at its outer ends are two triangular thickenings separated from one another by the posterior end of the cavity of the valve. These thickenings presumably represent the teeth, although as they do not project at all and cannot have been interlocked with anything in the dorsal valve it may be more accurate to regard them as the remains of dental plates. I shall refer to them as the dental areas. Each dental area is shallowly concave antero-posteriorly and in young examples is obscurely striated, the striæ running parallel to the median plane of the shell. At its antero-lateral corner each dental area passes directly into a thickening of the shell which runs round to meet the other in the middle line anteriorly. This thickening, which forms a very definite flange rising from the generally flat visceral surface of the valve, is thrown into loops, symmetrically disposed and pointing towards the cardinal region. In the youngest individual the only well-marked loop is axial in position, passing from the anterior margin more than half-way to the hinge-line. In older specimens this axial loop becomes much enlarged and may reach three-quarters of the distance from the anterior margin to the beak. In all the specimens except the youngest there are in addition two main pairs of loops symmetrically placed; of these the posterior is the larger. Finally there are other smaller emarginations which in still more aged individuals might be supposed to become loops. In certain specimens the outer parts of the loops may become confluent, forming a single ridge.

The flange is always highest at the inner end of a loop and shallower peripherally. The flange is sharp-margined, and, except in the loops, excavated on the inner side just below its edge so as to form a distinct ledge or rabbet. Outside the flange the shell is continued by a thin featureless adherent film to the irregular margin.

The muscle-markings are restricted to the posterior end, in fact lie largely between the dental areas. In full-grown individuals the inner margin of the dental area of the left side (spectator's left when the shell is placed with the hinge-line uppermost) is slightly excavated for an abductor muscle, whose insertion is on a narrow area on the side of the dental area, not reaching to the umbonal region, and in two individuals clearly limited to a small raised area with a distinct admedian margin.

In most specimens there is no distinct area for the insertion of an adductor on the left side, but in one or two where the shape of the surface on which the shell grew has led to the existence of a small hollow below the hinge-line and between the dental areas, this muscle is represented by a small well-marked depression, separate from the abductor insertion.



Schematic figure of the posterior region of the ventral valve of *Poikilosakos petaloides*. × 8. In this figure all the morphological facts to be seen in the whole series of specimens are introduced.

The adductor on the right side has a large and very well-marked insertion which occupies a long narrow area passing forward from the umbo nearly parallel to the inner edge of the dental area for a considerable distance, sometimes a quarter of the shell length. This muscle insertion is raised anteriorly on a special thickening of the shell, the edges of which grow up round the muscle so that the insertion lies at the bottom of a groove which may be of considerable depth. The walls of this groove are so placed as to show that the muscle passed obliquely across to the dorsal shell and was attached to it either on the middle line or beyond it on the left side. There is no evidence of the existence of an abductor muscle on the right side, as there is no such excavation of the dental area as forms its insertion on the left side, and the outer wall of the thickening for the insertion of the right adductor is often in close contact with the dental area in the region where the implacement should be.

The visceral surface of the shell is usually smooth, but in certain individuals has a pustulose surface exactly resembling that which is usually found on the visceral surface of the shells of *Strophalosia*. The shell shows no signs of being punctate, and apparently consists of a single layer. Apart from the ridges it is extremely thin, perhaps seldom exceeding ·1 mm.

The preceding description contains a purely objective statement of the facts shown in my specimens of this Brachiopod. From them it is possible to draw certain conclusions as to the structure of the dorsal valve and the animal's structure and habits.

It seems certain from the whole structure that the dorsal valve covered only the space included within the raised flange and that, when closed, its edge rested in the rabbet on the inner face of that rim; the margins of the shell would thus be uncovered all round, as they must certainly have been in the region posterior to the hinge-line. This disposition of the dorsal valve shows that the flange is really the edge of the ventral shell, the areas lying outside it being merely of the nature of callosities developed for more perfect fixation.

The fact that only a single asymmetrical abductor muscle can be recognized suggests that the two valves could not be opened widely, if at all, by a strict hinge action at the hinge-line, and the equally marked disparity between the adductors can only be explained by supposing that the action of the two kinds of muscles together was to slew the dorsal valve round on the ventral so as to bring the slits in the dorsal valve, which correspond to the loops of the flange of the ventral valve, over the areas between the loops, thus allowing a free circulation of water.

The differences between the very small and the large specimens show that the loops originally develop as notches on the edge of the dorsal valve by a failure to grow at certain spots on the edge of the mantle. The whole structure is, in fact, developed by an emargination of the edges of the shell similar to that which divides the valves of Bilobites or *Pygope* into such distinct halves.

From the very small unbroken area which remains inside the shell it seems certain that the lophophore could not have been spirally coiled as it is in most Brachiopods, but must have been persistently larval as it is in the Thecideidæ and *Argiope*, passing in front of the mouth and forming a decollated band following the edge of the dorsal valve.

For this Brachiopod I propose the name *Poikilosakos petaloides*, gen. et sp. nov. The original of Pl. XIV, Fig. 1, is the holotype.

Poikilosakos at once recalls *Keyserlingina* from the Uralian beds of Russia. From Tschernyschev's description of casts of the visceral surface of the ventral valve, which alone are known, it is obvious that the two forms resemble one another in having a large ventral valve, and a much smaller dorsal one whose edge is dissected and fits into a raised ridge on the ventral valve, which is thrown into quite similar loops in the two genera.

The text-figure given by Tschernyschev of the real appearance of the interior of the ventral valve as determined from the casts seems to me to be unworkable, and I prefer to leave any further comparison to those who are able to re-examine the specimens. There is no question of generic identity, as in *Keyserlingina* the ventral valve is strongly convex and probably not completely attached.

A far more interesting comparison is with *Leptodus* (=*Lyttonia*). Except that it is only attached by the umbonal region the young specimen of *L. americanus* figured by Girty, 1908, pl. iv, fig. 8, agrees extremely closely in its outline with our specimens, having an axial slit in the dorsal valve, and on the right side at any rate, when viewed from the dorsal surface, two lateral incisions. This specimen also shows a short straight hinge-line in the form of a groove, and distinct dental areas quite similar to those of *Poikilosakos*, so far as they are not concealed by the dorsal valve.

As Girty has pointed out, in his species the lateral "septa" of the ventral valve very often take the form of long, narrow loops, which, as shown in his pl. xxv, figs. 2 and 1*a*, are very like those of *Poikilosakos*. In *L. americana* the medium septum in the ventral valve bifurcates towards the anterior end, and the dorsal valve is always split by a medial incision from the anterior margin.

The figures of *Lyttonia nobilis* given by Waagen, pl. xxx, figs. 6 and 9, show that the muscular impressions on the ventral valve of shells of this genus agree with those of our new genus in being long and narrow in shape, very small in size, restricted to the extreme posterior end of the shell, and widely separated from one another anteriorly. These figures also suggest that there is some difference in size of the muscles of the two sides, though such disparity does not approach the remarkable condition seen in *Poikilosakos*.

These resemblances leave no doubt that *Poikilosakos* is a member of the Lyttoniidæ and that it is an early and primitive member of this group. Taken in connexion with *L. americanum* the comparison makes it certain that, as Girty has already suggested, the "septa" of *Lyttonia* both lateral and median are no true septa, but have arisen by the growing together of the edges of a deep slit in what is the functional and morphological, though not the real edge of the valve, a process which in exceptional regions of certain specimens of *Poikilosakos* has already taken place. This origin affords a simple explanation of the fact which Noetling has recorded, that the "septa" of the ventral valve of *Oldhamina* are double in structure. The fact that the remarkable pinnate dorsal valve of *Oldhamina* has developed by the excessive emargination of the shell, when considered in connexion with the probability that in *Poikilosakos* the lophophore was a continuous band following the margin of the dorsal valve which supports it, allows us to deduce a hypothetical structure and a theory of the functional arrangements of this remarkable type.

It is probable that in *Oldhamina* each pinna of the dorsal valve supported a double band of lophophore running its entire length, and that the median septum was provided with a strip of lophophore on either side. Noetling showed that each pinna of the dorsal valve rests its anterior edge on a "septum" of the ventral valve, so that the cavity of the shell forms a series of canals leading to a pair of central channels running antero-posteriorly. Each of the lateral canals is open to the outside by a slit running the entire length of the dorsal pinna, formed by the gap between that pinna and the one behind it. If we suppose that the ciliary currents are driven down these lateral canals and by the action of the strip of lophophore along the side of the median septum are urged towards the posterior end, we have a feeding arrangement which, though not exactly paralleled by anything we know, should have been as efficacious as we infer from the immense size of *Lyttonia* it must have been.

Since the time of Waagen it has been customary to refer *Oldhamina* and *Lyttonia* to a special sub-family Lyttoniinæ of the family Thecideidæ. This view has been accepted by subsequent authors, although only with great reserve by Noetling. The much less specialized *Poikilosakos* affords better material for comparison with *Thecideas* than the later *Oldhamina*. *Poikilosakos* and the true Thecideidæ have in common only the attachment of the ventral valve and the lobed lophophore.

The attachment of the ventral valve is not a feature of great systematic importance, as it has repeatedly arisen in Brachiopods. The lobed lophophore if strictly comparable in the two groups would be of much greater importance, but the early Lyttoniids, both *Poikilosakos* and *Keyserlingina*, show that the lobing of the lophophore in that group has developed in consequence of a notching of the edge of the dorsal valve, whilst the early true Thecideas, of which the first large series are of Upper Liassic age, show no trace of any incision of the margin of the dorsal valve, but suggest that the lobing of the lophophore has arisen in them through the upgrowth in the dorsal valve of true septa quite analogous with the median septum which in the life-history of all Terebratellidæ and Dallinæ notches the anterior margin of the primitively circular brachideal band.

There is thus no evidence at all that the Lyttoniidæ and the Thecideidæ are allied. The two groups differ markedly in the very early and complete loss of an area and delthyrium in the former and its retention in a typical form by the latter group, and in the great reduction of the muscles together with a probable loss of power of opening the shell in the earlier family contrasted with a highly developed musculature and a power of opening the shells at right angles in the Thecideidæ. It is thus necessary to place the two groups in independent families and to discuss their relationships separately.

The interesting Brachiopod *Pterophloios emmerichi* from the Kössen Beds deserves to be considered in the light of this distinction between the Thecideidæ and Lyttoniidæ. I know it only from a single dorsal valve in the British Museum, and from Zugmayer's figures. In shape it resembles a small *Oldhamina*, having strongly involute valves and being attached only by a small portion of the umbonal region. It has neither area nor deltidium. The "septa" which occur in both valves split at their outer ends and form a continuous band following the margin of the shell, and much more resemble the septa of the ventral valve of *Oldhamina* than of any true Thecidia. It differs from every known Lyttoniid in having a solid dorsal valve with a continuous margin. There is, however, no difficulty in supposing that the entire margin has secondarily developed by a fusion of the edges of the pinnæ of *Oldhamina* analogous to that which we have supposed to have formed the "septa" of the ventral valve of that form. I am therefore disposed to refer *Pterophloios* to the Lyttoniidæ, a family whose definition will then become:—

Family Lyttoniidæ.—Protremata cemented to a foreign object either throughout life or in youth by a ventral valve with area, delthyrium, and teeth vestigial or absent, with a flange on which the edge of the dorsal valve fits. Dorsal valve smaller than ventral and with a deeply slit margin, there being a single anterior median and paired lateral slits. The slits in the dorsal valve and the folds in the flange of the ventral valve which correspond to them may close up so as to form false septa, and produce secondarily an entire margin to the dorsal valve. The muscular insertions on the ventral valve are long, narrow, rather widely separated anteriorly, and may be very unsymmetrically developed.

Genus *Poikilosakos*, gen. nov.—Lyttoniids with the ventral valve cemented throughout life by its whole area. Only two pairs of lateral slits in the dorsal valve. Muscles asymmetrically developed, the abductor of one side and the adductor of the other alone being functional. Type, *Poikilosakos petaloides*, sp. nov. Cisco Beds (Uralian): Graham, Texas.

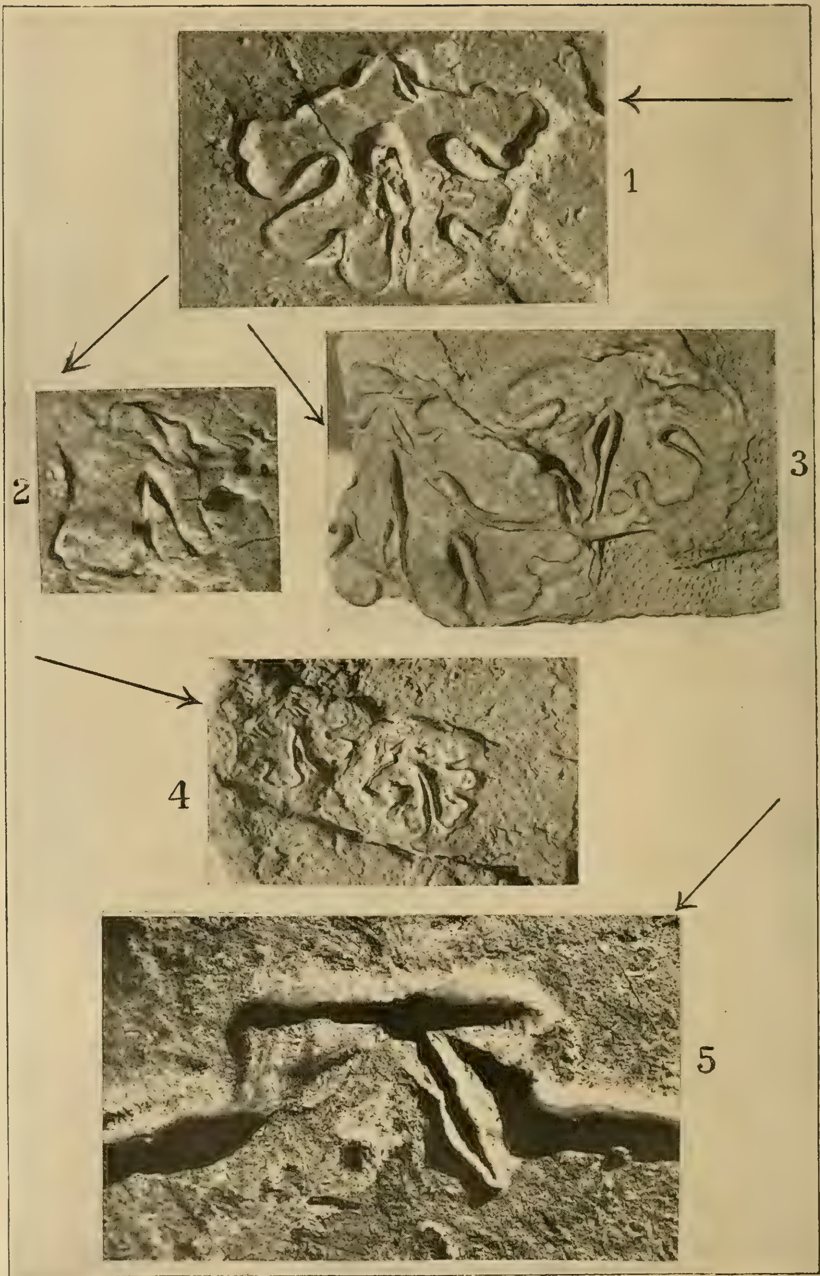
Keyserlingina, Tschernyschev.—Lyttoniid with the ventral valve strongly convex, cemented only by part of its area. Only two pairs of lateral slits in the dorsal valve. Type. K. Uralian: Timan, Russia, and the Carnic Alps.

Lyttonia, Waagen (=*Leptodus*, Richthofen).—Lyttoniids with very large, narrow, flat ventral valve, cemented only by the umbonal region. From ten to twenty-five pairs of lateral slits in the dorsal valve in adults. Folds in flange of ventral valve fused to form "septa". Muscles nearly symmetrical. Artinskian and later: Salt Range, India; Lo-ping, China; Guadaloup Mountains, Texas; Sosiokalk, Sicily; ? Timor.

Oldhamina, Waagen.—Lyttoniids with large, very convex, involute ventral valves, attached by the umbonal region in youth, subsequently becoming free and developing a callus over the posterior end. Very many pairs of lateral slits in the dorsal valve. Folds in flange of ventral valve fused to form septa. Post-Artinskian: Salt Range, India.

Pterophloios, Gümbel.—Small Lyttoniids with a convex ventral valve cemented only in youth by the umbo. About seven pairs of lateral slits in the dorsal valve. Edges of slits in the dorsal and folds in the flange of ventral valve fused so as to form septa, and restore an entire margin to dorsal valve. *Pterophloios emmerichi*, Gümbel. Rhætic: Kössen, Austria.

Beyond the fact that they were undoubtedly members of the Protremata, it is impossible to gain any idea of the ancestors of the Lyttoniidæ. It is natural to suppose that their ancestors retained an



F. Pittock, Phot.

POIKILOSAKOS PETALOIDES, *gen. and sp. nov.*

embryonic type of lophophore and had not developed the spirally coiled brachidium which we know to have occurred in many Strophomenids and Productids. When, however, a stage is retained in the life-history it seems not impossible that descendants of an animal which has passed that stage in its adult structure may nevertheless stop at such a stage, and hence be more primitive in their structure than their own immediate ancestors. It is therefore not impossible that the Lyttoniidæ have been derived from some Strophomenid, as in that group we get the closest parallel to the curious long narrow muscular insertions in the ventral valve.

I wish to express my thanks to the Trustees of the Percy Sladen Fund for the opportunity of visiting Texas and collecting the material on which this paper is based.

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EXPLANATION OF PLATE XIV.

Photographs of specimens of ventral valves of *Poikilosakos petaloides*, gen. et sp. nov., from the Cisco Beds, Upper Coal-measures, Graham, Young Co., Texas.

FIG. I. A large symmetrically developed specimen to be regarded as the holotype. × 2 approx.

II. A very small specimen. × 4 approx.

III. Two large irregular specimens, the left of interest because the edges of the right posterior lateral loop have grown together to form a false septum. × 2 approx.

IV. Two individuals of medium size. × 1.

V. The posterior part of a large shell. × 8 approx.

REVIEWS.

I.—A DESCRIPTIVE CATALOGUE OF THE METEORITES COMPRISED IN THE COLLECTION OF THE GEOLOGICAL SURVEY OF INDIA, CALCUTTA (on August 1, 1914). By J. COGGIN BROWN. Mem. Geol. Surv. India, vol. xliii, pt. ii, pp. 149–287, 1916.

THE collection of meteorites in the Calcutta Museum originated with the purchase, in 1865, from R. P. Greg (in this catalogue wrongly designated Professor) of his collection of meteorites. This collection must, of course, not be confused with the large collection of minerals, including meteorites, which belonged to his father, R. H. Greg, and was purchased by the Trustees of the British Museum in 1860. In 1868 the Calcutta collection was further enriched by the absorption of the specimens belonging to the Asiatic Society of Bengal, and at the date the catalogue was written included specimens representing 379 falls and finds.

The arrangement of the catalogue is alphabetical according to the name of the meteorite, and particular care has been taken to secure accuracy in the names of India meteorites. Under each entry we find the date of the fall or find, the locality, a description of the specimen, its registered number, and the weight. Brezina's classification is used.

A small piece of criticism that suggests itself is whether it is wise to issue a catalogue of this character among the memoirs of the Survey and not as a separate publication.

II.—Handbook and Descriptive Catalogue of the Meteorite Collections in the United States National Museum. By George P. Merrill. pp. x + 208, with 41 plates. Washington: Government Printing Office. 1916.

THIS excellent publication, which constitutes Bulletin No. 94 of the United States National Museum, comes from the pen of the well-known Head Curator of Geology in that Institution. In the preface he tells us that, while the book is intended primarily for the use of the general public, it is so arranged as to meet the requirements of the student and the investigator. The great difficulty that confronts the writer of a work of this kind is how much knowledge may be presumed of the average visitor to the museum, and therefore how much to say and how much to leave out; sometimes the attempt to keep the phraseology free from technicality results in the information given being at the best misleading and at the worst wrong. Mr. Merrill for his part has not hesitated to take the reader into comparatively deep waters, but the plunge should prove stimulating to anyone of at least average education. The frequent quotation of the results of chemical analyses may possibly have a forbidding appearance to readers unacquainted with their meaning.

The book is divided into two parts, of which the first, running to 28 pages, is really a compendious textbook on meteorites. A brief explanation is given of Brezina's cumbersome classification, which *faute de mieux* is retained in the book, and the constituent minerals of meteorites are described. A few pages are devoted to the structure of meteorites, particular attention being paid to the curious chondrules characteristic of many stones. The exact process by which these granular masses have been formed is still a little uncertain; in one peculiar type of stone—the Allegan—glassy chondrules are found in a crystalline matrix, which is contrary to what would have been expected. Mr. Merrill discusses on the usual lines the early records of meteorites, and the phenomena accompanying the fall. He, however, omits to say anything about their possible origin, or the light that the study of the solidification of alloys has thrown on the structure of the siderites and the metallic portion of aerolites.

The second part of the book consists of the catalogue of the collection of meteorites in the United States Museum. At the date of publication it contained specimens representing 329 falls and finds, but in addition it has been enriched by Dr. C. U. Shepard's bequest, after his death in 1915, of the meteorite collection brought together by his father, the late Professor C. U. Shepard, one of the earliest American mineralogists. The latter collection had been deposited in the Museum on loan for some years; it comprises 234 falls and finds, of which 83 were not represented in the general collection. The total number of falls and finds therefore represented in the Museum is 412. The present catalogue succeeds two others, the one written by Dr. F. W. Clarke in 1889 and the other by Mr. Wirt Tassin in 1902. Since they were compiled the entire collection has been re-arranged independent of the mineral collection, of which it had formerly been considered a part, and is now treated as belonging more properly to petrology. The arrangement of the catalogue is alphabetical under the names of the falls and finds, the names being nearly always derived from the locality. Under each entry are given the group in the system of classification to which the meteorite may be assigned, a description of the specimen in the collection, particulars of the fall, and other details, if known, such as the chemical composition, and at the close a reference to the literature from which the abstract has been compiled. For fuller information the reader is referred to Wülfing's *Die Meteoriten in Sammlungen und ihre Literatur*. The Shepard Collection is catalogued separately.

The book is certainly one that should be in the hands of all interested in the subject of those strange wanderers from cosmical space which have survived their fiery rush through the atmospheric envelope protecting the earth from constant bombardment.

III.—A recently found Iron Meteorite from Cookeville, Putnam County, Tennessee. By George P. Merrill. Proc. United States National Museum, vol. li, pp. 325–6, pl. xxviii, 1916.

THIS meteorite, which was found in 1913, is evidently very old because it was badly weathered. Its weight before cutting was 2,132 grams. It is made up of broad bands of kamacite, between which lie thin plates of tænite. Analysis shows the percentage composition to be mainly: nickel 6, iron 61, and iron oxide 28. The meteorite is in the possession of Ward's Natural Science Establishment.

IV.—Notes on the Whitfield County, Georgia, Meteoric Irons, with new Analyses. By George P. Merrill. Proc. United States National Museum, vol. li, pp. 447–9, pl. lxxviii, 1916.

IN 1881, in the *American Journal of Science*, W. E. Hidden described an iron meteorite from Whitfield County, but gave no analysis. In 1883 C. U. Shepard described a larger mass, weighing 117 lb., from near Dalton in the same county. In 1887 George P. Kunz suggested that the East Tennessee (Cleveland) iron might be identical with the large mass of Whitfield County iron. Examination of thin sections, however, revealed marked differences. The Hidden iron is marked by broad areas of plessite and a peculiar swelling of the kamacite bands, while between the two alloys are the regularly disposed, parallel lying tænite bands. In the Shepard iron the kamacite bands are not swollen, but show very straight borders, and the tænite bands are thinner, while it contains small, irregularly scattered, granular, and dendritic particles of schreibersite. The analyses gave similar figures, but that is not unusual in meteorites of this class. The author proposes the names Whitfield County and Dalton for the Hidden and Shepard irons respectively. The Cleveland iron also must belong to a distinct fall.

V.—On certain possible Distributions of Meteoric Bodies in the Solar System.[1] By Harold Jeffreys.

IN the third part of this paper the author deals with problems of fundamental importance to geologists, since it bears directly on the question of the initial condition of the earth, whether gaseous, molten, or solid. The following quotation from the introductory paragraph expresses the conclusions to which Mr. Jeffreys has arrived: "The objections to the Nebular Hypothesis are first summarized, and it is then shown that while the Planetesimal Hypothesis avoids most of them, it is nevertheless open to a new one, namely, that collisions between the small bodies would be so frequent, and would occur with so high a velocity, that the particles would be fused and volatilized long before accretion could produce any important effect on bodies as large as the planets. If the planetesimals be supposed to have moved initially in nearly circular orbits, this objection is avoided, but the planets are required to have always been very large."

VI.—Some Reactions involved in Secondary Copper Sulphide Enrichment. By E. G. Lies, E. T. Allen, and H. E. Merwin. *Economic Geology*, vol. xi, pp. 407–503, 1916.

THE reactions of a number of natural sulphides, viz. chalcocite ($Cu_2\,S$), covellite ($Cu\,S$), Bornite ($Cu_5\,Fe\,S_4$), chalcopyrite ($Cu\,Fe\,S_2$), pyrrhotite, pyrite ($Fe\,S_2$), sphalerite ($Zn\,S$), and galena ($Pb\,S$), with copper sulphate solutions in all cases, gave rise to a copper enrichment product, and in all cases the sulphate of the metal contained in the original sulphide was formed and usually sulphuric acid as well. Cupric sulphate acts as oxidizing agent, not only at elevated but also at lower temperatures. The sulphide enrichment products are crystalline and adhere firmly to the altered sulphide as in nature. The order of stability of these products towards cupric sulphate is: chalcopyrite, covellite, chalcocite. Rise of temperature affects the rate rather than the nature of the reaction, but at high temperatures hydrolysis plays a part.

[1] Monthly Notices of R.A.S., December, 1916, p. 84.

VII.—NOTE ON THE LINEAR FORCE OF GROWING CRYSTALS. By GEORGE F. BECKER and ARTHUR L. DAY. *Journal of Geology*, vol. xxiv, pp. 313–33, 1916.

THE object of this paper is to re-affirm the thesis made by the authors in 1905, viz. that the growth of crystals in saturated solution develops a linear force in the direction of the load, and that neither the magnitude of the load nor its character has any other effect than to increase solubility, and so to raise the concentration necessary for potential supersaturation and growth upon the loaded crystals. The statement had been called into question by Bruhns and Mecklenburg in 1913. The latter authors placed two crystals in a similar saturated solution, the one loaded and the other free, and remarked that the first did not lift its load. They entirely overlooked that the solubility of the loaded crystal is for most substances greater than that for the unloaded one, and further that the unloaded crystal supports weight (its own). If the supersaturation of the liquid be increased so that the free crystal cannot grow fast enough to keep the concentration down, then the loaded crystal also will grow.

VIII.—CRYSTALS AND CRYSTAL FORCES. By F. E. WRIGHT. Journ. Washington Acad. Sci., vol. vi, pp. 326–32, 1916.

IN this short paper the author briefly rehearses what is known of the structure of crystals and of interatomic forces, and considers the methods by which further knowledge may be obtained. Incidentally he mentions that at the Geophysical Laboratory at Washington apparatus has been built or is under construction for measuring accurately the changes in the crystallographical and optical constants of crystals for temperatures ranging from $-190°$ to $+1600°$ C., and for hydrostatic pressures ranging from 1 to 2000 atmospheres. He points out the striking fact in petrology, viz. the fewness of the rock-making mineral species, especially in igneous rocks, despite great diversity in conditions of formation and in chemical composition.

IX.—FOSSIL FISHES IN THE COLLECTION OF THE UNITED STATES NATIONAL MUSEUM. By CHARLES R. EASTMAN. Proc. U.S. Nat. Mus., vol. lii, pp. 235–304, pls. i–xxiii, 1917.

THE fossil fish-remains in the U.S. National Museum at Washington have lately been systematically arranged by Dr. Eastman, who now publishes some notes on the collection, with figures and descriptions of a few new species. Most interesting are the fragments from old Palæozoic formations, said to be of Ordovician age, in Colorado, Montana, and South Dakota. One portion of a dermal plate, named *Astraspis desiderata*, by Walcott, consists of tuberculated polygonal tesseræ, and is compared with the dorsomedian plate of *Psammosteus* and *Drepanaspis*. It is unfortunate, however, that no new studies of the microscopical structure of this and the associated fragments appear to have been made. In the account of Devonian fish-remains there are figures of a dorsomedian plate of *Ceraspis carinata* from the

Eifel, Germany, a spine of *Heteracanthus uddeni* from Iowa, and the upper dentition of the Arthrodiran *Dinognathus ferox* from Ohio. Carboniferous species are numerous, but for the most part very fragmentary. A new species of the peculiar spine, *Harpacanthus*, from the St. Louis Limestone, Missouri, is noteworthy. Triassic fishes are well represented in the Museum, and fragments of trunk from the Kanab Valley, Utah, are referred to a new species of *Lepidotus*, named *L. walcotti*, after their discoverer. The Jurassic and Cretaceous fishes are scarcely noticed, but a supposed new species of *Notagogus* is figured from the Lithographic Stone of Bavaria. Photographs of several Tertiary fishes are published, including *Parafundulus nevadensis*, gen. et sp. nov., from the Lahontan Beds, Nevada, and *Ameiurus primævus*, sp. nov., and *Priscacara dartonæ*, sp. nov., both from the Green River Shales of Wyoming.

X.—Dentition of *Ptychodus*.

Descrizione di un notevole esemplare di *Ptychodus*, Agassiz, trovato nel calcare bianco della Creta superiore di Gallio nei Sette Comuni (Veneto). By Professor Mario Canavari. Palæontographia Italica, vol. xxii, pp. 35–102, pls. v–xiv, 1916.

The natural arrangement of the teeth of *Ptychodus* in the jaw was first shown by specimens from the English Chalk, and next by a fine example of *P. mortoni* from the Chalk of Kansas, U.S.A. An unusually well-preserved dentition of both jaws has now been found in the Upper Senonian of Northern Italy, and is described in a beautifully illustrated exhaustive memoir by Professor Canavari.

The Italian specimen, which belongs to the variable group commonly known as *P. polygyrus* and is regarded as representing a new form or species, *P. mediterraneus*, must have originally comprised about 1,090 teeth in the two jaws. It shows the usual median row of diminutive teeth in one jaw, the relatively large median teeth in the other, and there seem to have been nine paired rows of teeth in each jaw. The former dentition measures at least 47 cm. in length by 44 cm. in breadth, while the latter measures at least 50 cm. by 42 cm. Professor Canavari thinks that the second would form a dental armature almost flat transversely, while the first would be gently arched from side to side. He therefore concludes that Dr. Smith Woodward was probably wrong in his determination of the upper and lower jaws of *Ptychodus*, and proposes to reverse them. Unfortunately, however, the supporting cartilages are only represented by fragments, so that the new specimen does not settle the question conclusively.

XI.—The Atlantic Slope *Arcas*. By Pearl G. Sheldon. Palæontographica Americana, i. pp. 100, with 16 plates.

We welcome this, the first number of a new publication, edited by the energetic Professor Gilbert D. Harris, of Cornell University. The memoir deals with the Recent and Tertiary species of the Lamellibranch *Arca*, found on the east coast of North America, and includes mention of Cretaceous species from elsewhere and of

Caribbean species. Each of the known species is described and compared with allied forms. The editor lays great stress on the illustrations. One or more specimens of each species have been photographed so as to bring out the diagnostic character, and Dr. Sheldon has spent two years in obtaining photographs which could be reproduced without retouching. These, as well as photographs of drawings previously published by Dall and others, have been mounted on a background apparently of dark American cloth, and reproduced in half-tone as quarto plates. Professor Harris holds that such plates are "practically as good as museum specimens for critical study", and that the publication of works of this character will therefore enable satisfactory investigation to be conducted in remote institutions. Experience alone can decide whether the photographs will bear out this enthusiastic claim. At present we can only say that, while the general effect is pleasing and most of the photographs very good, still the clearest illustrations on each plate are the reproduced drawings, and the outline of some of the more shaded and rounded specimens is far from distinct in the photographs. But, granting the contention of Professor Harris, we are all the more surprised that he should have thought it advisable to reproduce such fine plates on "art" paper, and to issue a work of such importance with the sheets transfixed by wire instead of being stitched. "Time only can tell," he says, whether the experiment will prove a success. In a fight with time it is unwise to handicap oneself by using perishable materials. The subscription rate is 2 cents per page and 10 cents per plate. Hence No. 1 may be had for $3.60 (15 shillings).

XII.—CRETACEOUS CRABS FROM S. DAKOTA.—Some crabs from the Pierre Shales are described by Miss Mary J. Rathbun (Feb. 1917, Proc. U.S. Nat. Mus., vol. 52, pp. 385–391, pls. 32, 33). One, called after the discoverer, *Dakoticancer overana* [why feminine?], gives rise to a new superfamily of Dromiacea, the *Dakoticancroideae* [!!!, at least three notes of abhorrence are needed for this mass of barbarisms], since the absence of longitudinal grooves from the sternum of the female removes it from the Dromioideae, while the sheltering orbits and the absence of *lineae anomuricae* distinguish it from the Homoloideae. "There is no complete specimen even of the carapace," but, though the description is completed, no reconstructed figure is attempted. A new species each of *Homolopsis* and *Campylostoma* are also described with care from a few imperfect specimens.

XIII.—THE FLORA OF THE FOX HILLS SANDSTONE. By F. H. KNOWLTON. U.S.A. Geological Survey, Prof. Paper 98–H, pp. 85–93, pls. xv–xviii. 1916.

THE marine formation of the Fox Hills Sandstone has hitherto yielded very few plant fossils, though it lies between two Upper Cretaceous deposits which are abundantly provided with plants. The present paper gives a list and descriptions of twelve vascular plants and one marine alga, of which only four species were previously known. The list includes one fern, one equisetum, four conifers, and six angiosperms, all save one represented by fragmentary impressions. The abundance of the alga, *Halymenites major*, Lesq., is an interesting feature, "countless thousands of specimens" being noted. A specimen of this added to the excellent illustrations would have made this first "Flora" of the Fox Hill Sandstones more complete, and more useful for those who are unprovided with the illustrations of the species first published in 1878.

XIV.—The Physical Conditions and Age indicated by the Flora of the Alum Bluff Formation. By E. W. Berry. U.S.A. Geological Survey, Prof. Paper 98–E, pp. 41–53, pls. vii–x. 1916.

THE Alum Bluff formation consists of marls and sands, of interest to palæobotanists because it represents practically the only horizon with a flora of uppermost Oligocene or basal Miocene in North America. Dr. Berry describes thirteen species, of which one is a fungus, one a Monocotyledon, and eleven are Dicotyledons. All are represented by fragmentary impressions, difficult to collect and preserve. Dr. Berry describes his method of embedding them in fresh plaster on the spot, by which means they survived the transportation to his laboratory. The most abundant species is the Monocotyledon, a palm, described as a new species of *Sabalites*. The flora is considered to be either Aquitanian or Burdigalian, "with a slight preponderance of the evidence in favour of the Aquitanian."

REPORTS AND PROCEEDINGS.

I.—The Palæontographical Society.

Annual General Meeting.

March 30, 1917.—Dr. Henry Woodward, F.R.S., President, in the Chair.

The Society having been founded on March 23, 1847, this was the seventieth anniversary. The annual report stated that the volume of monographs was again delayed by the circumstances of the time, but there was no lack of offers of palæontological work for publication, and it was expected that the forthcoming volume for 1916 would contain instalments of the monographs of Pliocene Mollusca, Palæozoic Asterozoa, Cambrian Trilobites, British Graptolites, and Wealden and Purbeck Fishes. Among members who had died during the year, Mr. C. T. Clough, Mr. Bedford McNeill, Mr. Clement Reid, and Miss A. F. Yule were specially mentioned. They were all valued supporters of the Society, and Mr. Clement Reid had done service on the Council. New members were much needed to replace the losses, and the Council appealed especially for the more active sympathy of the various Field Clubs and Natural History Societies.

Mr. H. A. Allen, Mr. E. Heron-Allen, Rev. H. N. Hutchinson, and Mr. C. T. Trechmann were elected new members of Council;

Dr. Henry Woodward, Mr. Robert S. Herries, and Dr. A. Smith Woodward were re-elected President, Treasurer, and Secretary respectively.

In a brief address, the President referred to the fact that when the Society was founded it was anticipated that all the British fossils could be described and figured in about twenty-five years, whereas the long series of fine volumes published during seventy years had only made a good beginning of the task.

II.—Geological Society of London.

1. *February* 28, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read:—

"Fourth Note on the Piltdown Gravel, with Evidence of a Second Skull of *Eoanthropus dawsoni*." By Arthur Smith Woodward, LL.D., F.R.S., V.P.G.S. With an Appendix on the Form of the Frontal Pole of an Endocranial Cast of *Eoanthropus dawsoni*. By Professor Grafton Elliot Smith, M.A., M.D., F.R.S.

Excavations last summer round the margin of the gravel-pit at Piltdown (Sussex) supported the conclusion that the deposit is a varied shingle-bank, and that the three layers containing Palæolithic remains and derived Pliocene fossils are approximately of the same age. Many elongated flints and pieces of Wealden sandstone were observed in the bottom sandy clay with their long axis more or less nearly vertical. No teeth or bones were found, but one nodular flint obtained from the same layer as *Eoanthropus* seems to have been used by man as a hammer-stone. This is not purposely shaped, but merely battered along faces that happened to be useful when the stone was conveniently held in the hand.

In the winter of 1915 the late Mr. Charles Dawson discovered in a ploughed field, about a mile distant from the original spot, the inner supraorbital part of a frontal bone, the middle of an occipital bone, and a left lower first molar tooth, all evidently human. These are rolled fragments, and the first and third may be referred with certainty to *Eoanthropus dawsoni*; but it is doubtful whether they represent more than one individual. In mineralized condition they agree with the remains of the type-specimen. The piece of frontal bone exhibits the characteristic texture and thickness, with only a very slight supraciliary ridge, and a small development of air-sinuses. The occipital bone is somewhat less thickened than that of the original specimen of *Eoanthropus*, and bears the impression of a less unsymmetrical brain. The external occipital protuberance is a little above the upper limit of the cerebellum, as in Neanderthal man; thus differing from the condition both in *Eoanthropus* and in modern man. The lower molar is exactly similar to the first lower molar of *Eoanthropus* already described, but is more obliquely worn by mastication. Detailed comparison shows that this tooth is human, differing essentially from that of a chimpanzee in its more hypsodont crown, thicker enamel, and less prominence of the neck over the root.

The occurrence of the same type of frontal bone with the same type of lower molar in two distinct localities, adds to the probability of their belonging to one and the same species. With these remains were found brown flints in great abundance, and one rolled portion of a lower molar tooth of *Rhinoceros* in the same highly mineralized condition as the derived Pliocene teeth at Piltdown.

In an Appendix, Professor G. Elliot Smith expresses the opinion that the endocranial cast of the fragment of frontal bone presents features more primitive and more ape-like than those of any other known member of the human family.

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2. *March* 14, 1917.—Dr. A. Smith Woodward, F.R.S., Vice-President, in the Chair.

The following communication was read:—

"The Carboniferous Limestone bordering the Leicestershire Coalfield." By Leonard Miles Parsons, D.I.C., B.Sc., F.G.S.

The inliers of Carboniferous Limestone situated along the northern border of the Leicestershire Coalfield crop out in two well-defined series—a Western series composed of almost horizontal beds exposed by stream-erosion, and an Eastern series in which the limestone is highly inclined and complicated by faulting. The thinly-bedded limestones, shales, and dolomites of the Western inliers are of a slightly higher horizon than that of the uppermost beds of the more massive dolomites seen at Breedon and Breedon Cloud farther eastwards. In no part of the district is the base of the Carboniferous seen, although borings have shown that the limestone rests upon pre-Cambrian rocks in the neighbourhood of Charnwood Forest.

The dolomites of the area yield evidence of two distinct periods of dolomitization—one pre-Triassic, the other subsequent to the Trias. During the former period the bulk of the rock was dolomitized.

The fauna of the limestones and dolomites indicates the presence of palæontological horizons ranging from D_1 to D_2–D_3 inclusive. The D_1 portion of the sequence, consisting of thickly-bedded dolomites without chert, contains a fauna similar to that of the Caldon Low facies of the south-western part of the Main Midland Province, the rare species *Productus humerosus* being found at Breedon and Breedon Cloud.

Unlike the rocks of the D_1 subzone of Derbyshire, the corresponding beds in Leicestershire contain no igneous rocks equivalent to the "Toadstones". Higher dolomites with chert, equivalent to the cherty limestones of Derbyshire, yield a D_2 fauna, which somewhat resembles that of the localized development of the *Lonsdaleia* subzone in the south-western part of the Midland area, in the region of Waterhouses.

A typical D_3 development is not present in Leicestershire, although the upper barren dolomites of Ticknall may represent part of the *Cyathaxonia* subzone of other districts.

The Pendleside Beds are poorly represented by about 30 feet of blue shales, which are succeeded conformably by the Millstone Grit.

3. *March* 28, 1917.—Dr. Alfred Harker, 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 Arthur Holmes, D.I.C., B.Sc., F.G.S., who proposes to conduct researches in connexion with the Geology of the Dartmoor Border, around Okehampton and Belstone.

The following communication was read:—

"The Carboniferous Limestone Series on the South-Eastern Margin of the South Wales Coalfield." By Frank Dixey, M.Sc., F.G.S., and Thomas Franklin Sibly, D.Sc., F.G.S., University College of South Wales and Monmouthshire, Cardiff.

The outcrop dealt with extends from the valley of the Ewenny River near Bridgend (Glamorgan) to that of the Ebbw River at Risca (Monmouth), a distance of about 19 miles from west-south-west to east-north-east. It is traversed by the Rivers Ely, Taff, and Rhymney.

Traced north-eastwards along this outcrop, the Carboniferous Limestone Series suffers much attenuation, and becomes mainly dolomitic, as shown by the officers of H.M. Geological Survey during the recent re-survey of the coalfield.

The table on p. 230 summarizes the succession in the western part of the district.

The *Lonsdaleia* subzone (D_2) has not been recognized, and if represented, it is probably incomplete. Contemporaneous dolomitization is of comparatively small vertical extent.

At Risca the total thickness has diminished from 2,700 feet to 800 feet, made up as follows:—

	Feet.	
$C_2 + S_1$, C_1, Z	675	Main Limestone.
K	125	Lower Limestone Shales.
	800	

There the Main Limestone is almost wholly dolomitic, and nearly barren of fossils. Its lower portion consists of crystalline dolomites, which represent contemporaneously altered standard limestones. Its upper portion, composed of dolomite mudstones with bands of crystalline dolomite and a very small thickness of calcitic oolite and calcite mudstone, is a *Modiola* phase extending from some level in C_1 up into S_1. The Lower Limestone Shales maintain a normal character.

The great reduction of thickness is due to two factors, in about equal degree:—

1. Unconformable overstep by the Millstone Grit. This cuts out the *Dibunophyllum* beds and the Main *Seminula* Zone. (Overstep is very gradual along most of the outcrop, but it becomes rapid at those points where the zones of the Carboniferous Limestone swing more sharply north-eastwards.)
2. Attenuation of the surviving zones. (This is rapid in the area east of the Taff.)

SYNOPSIS OF THE SUCCESSION IN THE WESTERN PART OF THE OUTCROP (WEST OF THE CREIGIAU FAULT).

	ZONE OR SUBZONE.		APPROXIMATE THICKNESS IN FEET.	
UPPER AVONIAN.	*Dibunophyllum* Zone[1] (?) D_2 (in part). D_1	Limestones including pseudobreccias.	600 (seen)	Main Limestone.
	Main *Seminula* Zone S_2.	*Modiola* phase, characterized especially by limestones with pisolitic structures. *Seminula* Oolite.	550 to 600	
	Upper *Caninia* Zone C_2+S_1.	Limestones, including much oolite. *Modiola* phase.[2]	350	
LOWER AVONIAN.	Lower *Caninia* Zone C_1.	*Caninia* Oolite. *Laminosa* Dolomite. (γC_1) Crinoidal limestones.	550	
	Zaphrentis Zone Z.	Crinoidal limestones and dolomites: cherts near the base.	250	
	Cleistopora Zone K.	(K_2) Shale with thin limestones. (K_1 or K_2) Crinoidal limestone and oolite. (K_1)[3] Shales and limestones.	300 to 350	Lower Limestone Shales.

[1] Present only in the area west of the Ely River. [2] Detected at one locality only (Miskin).

[3] Correlation inferred from the development east of the Taff, where the Lower Limestone Shales are better exposed and K_1 is found to contain a *Modiola* phase characterized by limestones of *a*-type.

The change of lithological and faunal character in the zones which escape overstep is due to:—

3. Progressive increase in the vertical extent of contemporaneous dolomitization; supplemented, in the area east of the Taff, by a great development of *Modiola*-phase deposits in which dolomite mudstones predominate.

The outcrop now described supplies, therefore, a key to the remarkably attenuated development of the Carboniferous Limestone Series which is known to prevail on the eastern and north-eastern borders of the coalfield. Overstep and actual thinning are both operating in a north-easterly direction to produce great attenuation.

The unconformity between the Carboniferous Limestone and the Millstone Grit is doubtless due to the earth-movement which caused flagrant unconformity between Lower and Upper Carboniferous in the Forest of Dean.

A detailed description of the lithological and faunal succession is given. The physical features of the outcrop are described, and attention is drawn to the remarkably perfect adjustment of minor drainage-lines to geological structure. The paper is illustrated by maps on which the zonal divisions are indicated, by horizontal and vertical sections, and by photographs which depict some of the most interesting features of the scenery.

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4. *April* 18, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read:—

"The Development and Morphology of the Ammonite Septum." By Professor Henry Hurd Swinnerton, D.Sc., F.G.S., and A. E. Trueman, M.Sc.

Two methods of studying the septum (not merely the suture) were used:—

1. Cleaning the face of the septum completely.
2. Filing away the surface of the whorl in successive layers, and thus making a series of sections—called septal sections—of the septum parallel to its periphery.

An instrument was designed for measuring accurately the variations in level of the face of the septum in relation to a definite datum-plane; and also the thickness of the layers filed off from the whorl.

Dactylioceras commune, *Sphæroceras brongniarti*, and *Tragophylloceras loscombi* were chosen as types with normally shaped, greatly depressed, and greatly elevated whorls respectively.

A contoured plan, of the adult septum of *Dactylioceras*, shows that half the septum lies approximately in one plane; and that the posterior folds or lobes occupy a greater area than the anterior folds or saddles. It also confirms the view that the septum is on the whole convex forwards. In all three types the axes of the folds remain approximately at right angles to the periphery through all the changes of whorl shape. Incompletely formed septa indicate that secretion commences at the umbilical angle and at a definite distance from the preceding septum.

The examination of adult sutures of various species of *Dactylioceras* shows that the major frillings alone are of systematic importance for that genus. The variations in the minor frillings, and in the suture-line as a whole, throw light on the changes which accompany senile decline.

The second septum is remarkably like the central portion of the adult septum; but the flattened portion is relatively less extensive, the folds are sharper, and the whole septum tends to be concave rather than convex. As development advances the successive septa possess a similar resemblance to an increasing area of the adult septum. The outcome of this is, that a series of septal sections of the latter closely resembles the developmental series of the suture-line in all three types.

In no case do the septal sections show a stage comparable with the first suture-line. In *Tragophylloceras* the similarity starts not later than the seventh septum. With these exceptions, septal sections reproduce the main features in the development of the sutures with sufficient accuracy to justify their use for the same purpose, especially when the material for the study of the early stages is inaccessible.

It is possible that septal sections may also furnish the clue to the probable lines along which simplification of the suture proceeds in the retrogressive members of any stock.

Asymmetry of the septum, and of the suture-line, in ammonites is more common than is usually supposed. It may arise in two forms, namely:—

1. By the different development of the elements of opposite side.
2. By association with the lateral displacement of the siphuncle.

Asymmetry of the latter type has been considered as of systematic importance. Nevertheless, while it does occur more frequently in certain genera, as, for instance, in *Psiloceras* and *Hoplites*, it occurs not uncommonly in many other unkeeled ammonites.

III.—Mineralogical Society.

March 20, 1917.—W. Barlow, F.R.S., President, in the Chair.

A. Holmes & Dr. H. F. Harwood: The Basaltic Rocks of Spitzbergen and Franz Joseph Land, with conclusions regarding the Brito-Arctic Tertiary Petrographic Province. These rocks, which were obtained respectively from Professor Garwood and the Geological Survey of England and Wales, are very similar, not only to the basaltic rocks previously described from neighbouring localities, but also to the basalts of the whole Arctic region stretching from Dickson Harbour to West Greenland. The essential minerals are labradorite rich in the anorthite molecule, pyroxene of the enstatite-augite type, and titaniferous magnetite. The province as a whole displays significant variations both in time and space. The earliest eruptions are generally poor in alkalies, but tend to become more alkaline as the present period is approached. Thus, the later eruptions of Spitzbergen gave rise to olivine trachydiorites instead of basalt. Jan Mayen still possesses an active volcano, and its rocks are unusually alkaline basalts. Similarly, the later rocks of Iceland, and, to a lesser extent, of Skye and the Small Isles, follow the same course. In space the most remarkable variation is seen in the distribution of titanium, the percentages of titanium oxide being high in the rocks of Greenland and the Iceland Ridge, and falling away regularly on each side. The Brito-Arctic Petrographic Province can be subdivided into five regions, viz. the British, the Icelandic (including the Faroe Islands and the Scoresby Sound district), the West Greenland, the Jan Mayen, and the Spitzbergen – Franz Joseph Land – Dickson Harbour, and the differences subsisting between them are related to the processes whereby the igneous activity was initiated. It is suggested that a petrographic province consists of a number of adjacent regions of igneous activity, in which similar rocks, or similar series of rocks, have been produced, whence it follows that the processes by which the magmas have been formed, differentiated, and intruded must be similar, and the underlying materials on which these processes have acted must also be similar.

Dr. J. W. Evans: A General Proof of the Limitation of the Symmetry Numbers of Crystals. On the assumption that crystals are composed of cells identical in all respects, then, if n be the degree of the symmetry of an axis and d an integer, the equation $\cos\frac{2\pi}{n} = \frac{1}{2}(1-d)$ must be satisfied. The only possible values of d are 3, 2, 1, 0, the corresponding values of n being 2, 3, 4, 6.

E. S. Federov: The Numerical Relation between Zones and Faces of a Polyhedron. The numerical relation shown by axes of symmetry situated in planes of symmetry pointed out by G. Cesàro in 1915 is only a particular case of the more general one deduced by the author in 1885.

A. Ledoux, T. L. Walker, and A. C. Wheatley: The Crystallization of Parahopeite. Crystals in the Royal Ontario Museum of Mineralogy from the original locality, Broken Hill, North-Western Rhodesia, are triclinic with the axial ratios $a : b : c = 0{\cdot}7729 : 1 : 0{\cdot}7124$; $\alpha = 93° 22'$, $\beta = 91° 12'$, $\gamma = 91° 22'$. Thirty-two forms are recorded. The crystals have perfect cleavage parallel to the brachypinacoid, and show lamellar twinning parallel to the macropinacoid. The angle of optical extinction on the cleavage is 10° with reference to the twin-lamellæ.

IV.—Edinburgh Geological Society (February 21, 1917).—"The Submarine Contours around the Orkney Islands." By Dr. Flett, LL.D., F.R.S., President of the Society. Dr. Flett pointed out that geologists were agreed that the main physical features of the north-east of Scotland were developed long before the Glacial period, and that the Orkneys were a northward continuation of the Caithness plain which had suffered depression, and had been partly overflowed by the sea. The principal sounds crossing the islands in a north-west to south-east direction were the valleys of old rivers like those of Caithness and Sutherland. At what date the land sank was not definitely established, but Orkney was probably joined to Caithness when the present assemblage of animals entered the islands. Along the east side of the archipelago the principal submarine feature is a steep bank rising from depths of 35–40 fathoms to about 20 fathoms. It has a general N.N.E. direction and a very straight trend, and undoubtedly is a continuation of the east coast of Caithness, which is to be correlated with the great fault that winds down past Brora and Helmsdale, bringing in the Secondary rocks on its eastern side. This is distinctly a land feature now submerged. Dr. Flett showed that the land had sunk in stages; periods of rapid depression alternated with pauses when subsidence was slow. In this way he explained the origin of certain very level areas on the sea bottom, covering wide stretches around the islands. One of these submarine flats lay at a depth of 18 fathoms and the other at 8 fathoms. At different periods Scapa Flow and Kirkwall Bay were large fresh-water lakes surrounded by swampy land. These changes had taken place since Neolithic man first inhabited the islands. In Sutherlandshire the land had risen to some extent, as was shown by raised-beach platforms at 100, 50, and 25 feet above the present sea-level. It seemed in every way probable that while Scotland as a whole was rising, Orkney and also Shetland were being submerged, and the submarine flats of Orkney corresponded in origin and date to the raised beaches of the rest of Scotland.

V.—Liverpool Geological Society.

March 13, 1917.—J. H. Milton, Esq., F.G.S., F.L.S., President, in the Chair.

The following papers were read:—

1. "On an interesting Occurrence of Secondary Rutile in the Millstone Grit." By H. W. Greenwood.

The grit in which the rutile occurs forms the base of a long ridge of hill which commences about a mile north-east of Macclesfield, runs for about two miles in a northerly direction, and terminates just above the village of Bollington. The particular exposure described occurs in a quarry on the hillside overlooking Bollington. The rock contains a quantity of light yellowish interstitial decomposition product, and it is in this and also in small cavities lined with iron-stained debris that the secondary rutile occurs in little glistening grains of a brilliant pink colour, sometimes deepening to a port wine tint. In some parts of the rock the crystals occur in such quantity as to become the dominant heavy mineral. The evidence points to the rutile having been formed from the alteration of a titaniferous biotite. In addition to the secondary rutile there are also deep yellowish red usually rounded grains which form part of the original constituents of the rock. Anatase is also abundant, generally growing on leucoxene, and staurolite was also noted.

2. "A Comparison between the Structure of the Assynt District of North-West Scotland and that of the Swiss Fore Alps." By J. S. Daly, B.A.

A detailed analysis of the structure of both regions was first given, and the similarity between them then made clear in an interesting manner.

CORRESPONDENCE.

POST-GLACIAL UPLIFT IN NORWAY.

Sir,—Please add the following reference to that one already given in my review, "Irregularities in the Post-Glacial Uplift of Norway," Geological Magazine for April, p. 174:—

Gunnar Holmsen, "De brædæmte sjøer i Nordre Østerdalen": *Naturen*, Feb. 1917, Bergen, pp. 48–60.

This paper has just arrived: it is a little fuller in some respects than the one already cited.

Leonard Hawkes.

Eversley,
Stow Park Avenue,
Newport, Mon.

THE ALKALINE ROCKS OF SOUTH-WEST AFRICA.

Sir,—In the Geological Magazine for December, 1915, you published a letter from me under the above title. In that letter I expressed the intention of visiting the occurrences of alkaline rocks [in the desert south of Lüderitz Bay], and of describing the rocks in detail. I was aware at the time that Professor Erich Kaiser, the distinguished petrologist of Giessen, was in South-West Africa, but I was not aware that he had come out from Europe for the express purpose of studying these very rocks. I have now returned from a visit to South-West Africa, where I had the pleasure of renewing my acquaintance with Professor Kaiser, and I learned that he has utilized his enforced leisure in the country (as a prisoner of war) by studying these alkaline rocks most minutely and mapping the occurrences on special, large scale topographic sheets prepared for the requirements of the diamond-mining companies. Professor Kaiser and Dr. Betz most kindly arranged an extensive tour for me, when I was able to visit and collect material from all the principal localities. Under the circumstances I must of course renounce my intention of writing anything more about these rocks until Professor Kaiser's memoir appears; I can only assure you that that memoir, when it does appear, will possess a quite extraordinary interest for petrologists.

S. J. Shand.

Geology Department,
Victoria College,
Stellenbosch, S.A.
February 8, 1917.

OBITUARY.

CHARLES BARRINGTON BROWN, Assoc. R.S.M., F.G.S.

Born August 23, 1839. Died February 13, 1917.

Charles Barrington Brown was the second son of Richard Brown, F.G.S., F.R.G.S., of Cape Breton, Nova Scotia, the author of several papers contributed to the earliest volumes of the Quarterly Journal of the Geological Society, whose drawings of sections of the Cape Breton coal-fields are found in most geological textbooks since Lyell's *Principles.*

Born at Cape Breton, he was educated at Harvard University, and at the Royal School of Mines, London (1862–4), taking his associateship in Geology. On the recommendation of Sir Charles Lyell, a close friend of his father, he was appointed to the Geological Survey of the West Indies (Jamaica) and of British Guiana (Demerara), on which he served with J. G. Sawkins from 1864 to 1870. For the next four years, from 1870 to 1873, he was in sole charge of the Survey. His reports on the Geology of British Guiana and of Jamaica in collaboration with that geologist are still the standard works on the subject, and earned the commendation of the Governors of those colonies.

During his travels on the Potaro River, a tributary of the Essequebo, he made the discovery, in April, 1870, of the famous Kaieteur Falls, the highest known true waterfall in the world, 822 feet in height and 123 yards wide; the chief wonder of British Guiana. An account of this discovery is to be found in one of Barrington Brown's books, *Canoe and Camp Life in British Guiana*, London, 1877, and in the Journal of the Royal Geographical Society (vol. xli, 1871). This is his description of the discovery:—

"Descending the river [Potaro] rapidly all day, we came within sound of the roar of a large fall. . . . When we came to the northern end of the savanna I observed that heavy masses of vapour were drifting before the north-east wind, making the trees, grass, and shrubs on our right dripping wet. This came from the great fall, to which we were in close proximity, but which was hidden from view by a grove of trees. Making a detour to the right through this grove, we came out on the flat rocks at the head of the great fall, and walking to the edge of the precipice, down which the water was precipitated, I gazed with wonder and delight at the singular and magnificent sight that lay before me.

"Not being prepared for anything so grand and startling I could not at first believe my eyes, but felt that it was all a dream.

"There, however, was the dark, silent flow of water down which we had travelled, passing slowly but surely to the brink of a great precipice, and breaking into ripples as it approached its doom. Then curving over the edge in a smooth mass of brownish tinge, changing into snow-white fleecy foam, it was precipitated downwards into a black seething cauldron hundreds of feet below. . . . I was prepared to meet with great falls on our way down . . . but nothing of so grand and extraordinary a nature as this ever entered my mind for a moment."

Shortly afterwards he discovered the less well-known but nevertheless remarkable fall of Ourindouie, on the Ireng River, a tributary of the Rio Branco. It may be remembered that a Dr. Bovallius announced, in 1907, the discovery of a waterfall on that river "rivalling Niagara", which he proposed to call the "Chamberlain Fall". Brown, on reading this account, recognized a description of the Ourindouie Fall, and was able to prove its identity by publishing a sketch he had made of the fall, in 1870, in the *Daily Graphic* of November 29, 1907. Accounts of this fall, and of the mysterious mountain of Roraima, which, in common with Sir Robert Schomburgk, at an earlier date, he in vain tried to ascend, are found in the above-mentioned book.

In 1873 to 1875 he was engaged in further exploration of the Amazon River and its tributaries for the Amazon Steam Navigation Company; an account of his travels is given in his *Fifteen Thousand Miles on the Amazon and its Tributaries*, London, 1878. Again, in 1887, 1889, and 1891 he examined gold placers and reefs in British Guiana, and also at other times in Surinam.

During this period, too, he was appointed by the Secretary of State for India to report on the ruby mines of Burmah, which resulted in a paper, written in conjunction with Professor J. W. Judd, which was published in the *Philosophical Transactions* of the Royal Society of London in 1896. This work is regarded as a classic contribution to the history of corundum.

Thereafter, in 1889 to 1902, he devoted his time chiefly to the mining of gem-stones in North Carolina, Ceylon, and New South Wales, at Inverell; and in later years was interested in the development of certain graphite mines in Ceylon.

Towards the latter part of his life, the hardships and vicissitudes of travel in such varying climates, and the fevers contracted on the Amazons, began to tell on his iron constitution, and it is almost surprising that he reached the advanced age of 77 years.

He had that rare quality of endearing himself to those with whom he came in contact, whatever their race or creed; and was a close associate of such men as Judd and Bennett Brough.

A lifelong friend, Dr. G. R. M. Pollard, who travelled with him in British Guiana, wrote of Barrington Brown: "There was no one more popular amongst his fellows than he, and I cherish the memories of many pleasant hours spent in his companionship. There was one characteristic that impressed everybody who came into business relationship with him, and that was his absolute integrity. His word was his bond; and his transparent honesty of purpose and fairness of dealing enabled him to manage and control, without difficulty, the many uncertain tempers of the men he had to employ in subordinate positions."

Besides contributing various papers to the Quarterly Journal of the Geological Society of London, to which he was elected a Fellow in 1879, and to the Journal of the Anthropological Society, he presented specimens, collected in his travels, to the Royal Gardens at Kew, the British Museum, and the Royal United Service Institution at Whitehall. A list of his published works is appended (p. 238).

After a life full of years useful to the cause of science and to our knowledge of the world, he passed away peacefully, in London, in his 78th year.

C. B. B., JUN.

A LIST OF PUBLISHED WORKS BY C. BARRINGTON BROWN.

1869. Reports on the Geology of Jamaica, or Part II of the West Indian Survey; by JAMES G. SAWKINS, F.G.S., with contributions by C. B. BROWN. London.
1871. Report on the Kaieteur Waterfall of British Guiana; with a map: Journ. Roy. Geogr. Soc., vol. xli.
1872. "Indian Picture Writing in British Guiana": Journ. Anthrop. Inst. Gt. Britain and Ireland, vol. ii.
1875. Reports on the Physical, Descriptive, and Economic Geology of British Guiana; by CHARLES B. BROWN, F.G.S., and J. G. SAWKINS, F.G.S. London.
1877. *Canoe and Camp Life in British Guiana.* London.
1878. *Fifteen Thousand Miles on the Amazon and its Tributaries*; by C. BARRINGTON BROWN, A.R.S.M., and WILLIAM LIDSTONE, C.E. London.
1879. "On the Tertiary Deposits on the Solimões and Javary Rivers in Brazil"; with an Appendix by R. ETHERIDGE, F.R.S., F.G.S.: Q.J.G.S., vol. xxxv.
1879. "On the Ancient River Deposit of the Amazon": Q.J.G.S., vol. xxxv.
1888. Report on the Ruby Mines of Burmah, June 15, 1888.
1889. "Rocks and Minerals of British Guiana": Journ. Roy. Agric. & Comm. Soc. British Guiana, vol. iii.
1896. "The Rubies of Burma and Associated Minerals: their occurrence, origin, and metamorphoses: a contribution to the history of Corundum"; by C. BARRINGTON BROWN, A.R.S.M., F.G.S., and J. W. JUDD, C.B., LL.D., F.R.S., F.G.S.: Phil. Trans. Roy. Soc., vol. clxxxvii.

RICHARD HILL TIDDEMAN, M.A. (OXON.), F.G.S., ETC.

BORN FEBRUARY 11, 1842. DIED FEBRUARY 20, 1917.

WE have to record the loss of Mr. Richard Hill Tiddeman, M.A., F.G.S., who from 1864 to 1902, for thirty-eight years, held the post of Geologist on the Geological Survey of England and Wales, during which time he served under four successive Directors: Murchison, Ramsay, Geikie, and Teall.

His principal work was in connexion with the Carboniferous Rocks of Yorkshire and the neighbouring counties of Cumberland and Lancashire, on which he was occupied for about twenty years. Later he did good work in North Wales. He was recognized as one of the leading authorities on these deposits and his knowledge was always willingly imparted to other workers, to whom he was an ideal companion and guide. In appreciation of his services the Yorkshire Geological Society elected him their President in 1914, and during his term of office he was a most valuable guide and instructor in the field and at the Society's meetings.

In presenting the Murchison Medal to Mr. Tiddeman in 1911, Professor Watts, the President of the Geological Society, said: "Ever since the beginning of Mr. Tiddeman's work for the Geological Survey on the borders of Yorkshire and Lancashire he has kept his eyes open to the observation of exceptional facts, and his mind employed in working out explanations for them. The excavation of the Victoria Cave, Settle, in which he took so active a part gave us valuable information on the history of the Pleistocene Mammalia; his work on the glaciation of North Lancashire still remains 'a model and a basis for glacial work all over the country'; his observations on the faunas of the Carboniferous 'Reef-knolls' of the North of England have put on record a wealth of observation and reasoning which will contribute no little to the solution of the problems presented by these remarkable structures; and his researches upon the raised beaches of Gower covered with glacial deposits have extended the area of known Pleistocene movement beyond Yorkshire and Cork."

A Yorkshire geologist writes of him in the *Naturalist* (April, 1917, p. 142): "Mr. R. H. Tiddeman, so well-known and beloved by Yorkshire hammer-men, has passed away. He was a quiet and conscientious worker, and made many firm friends in the county in which he did so much good work."

On his retirement from the Survey in 1902, he took up his residence in Oxford, but he was a frequent attendant at the meetings of the Geological Society in London, and was a member of its Council. He leaves a widow and two daughters.

Mr. Tiddeman was not a voluminous writer, but he contributed to many of the Survey memoirs, maps, and other publications. The Geological Survey memoir *On the Water-supply of Oxfordshire* bears his name. The following papers are also by Mr. Tiddeman :—

1872. "On the Evidence for the Ice-sheet in North Lancashire and adjoining parts of Yorkshire and Westmoreland": Q.J. Geol. Soc., vol. xxviii, pp. 471–91.

1873. "The Older Deposits in the Victoria Cave, Settle, Yorkshire": GEOL. MAG., pp. 11–16.

1894. "Carboniferous Trilobites from the Banks of the Hodder, near Stonyhurst, Lancs," by Henry Woodward [with "Notes on the Geology", by R. H. T.]: ibid., pp. 481–2.

1900. "On the Age of the Raised Beach of Southern Britain as seen in Gower": ibid., pp. 441–3.

1901. "On the Formation of Reef-knolls": ibid., pp. 20–3.

HARRY PAGE WOODWARD, J.P., F.G.S., Assoc. Mem. Inst. C.E.

BORN MAY 16, 1858. DIED FEBRUARY 7, 1917.

WITH deep regret we received, by the mail of March 31, the announcement of the death on February 7 at Perth, West Australia, of Harry Page Woodward, eldest and sole surviving son of Dr. Henry Woodward, the Editor of this Magazine and for many years Keeper of the Geological Department in the British Museum.

H. P. Woodward was educated at University College School, London, and at the Royal College of Science, South Kensington, where he studied geology under Professor Judd, and field-work with his cousin Mr. Horace B. Woodward, F.R.S., of the Geological Survey of England and Wales. In 1883, upon the recommendation of Sir A. Geikie, K.C.B., and Professor J. W. Judd, C.B., he was appointed Assistant Government Geologist to the Colony of South Australia, where he did valuable work for three and a half years. In 1886 he returned to London and spent a year in the Metallurgical Laboratory of the Royal College of Science. In December, 1887, he was appointed by the Secretary of State for the Colonies to the post of Government Geologist for Western Australia, where he has ever since resided. In 1895 he resigned his appointment as Government Geologist and entered the service of Messrs. Bewick, Moreing & Co., the Colonial Government conferring upon him the title of Honorary Consulting Geologist and Mining Engineer to the Colony. In 1883 Mr. H. P. Woodward was made a Justice of the Peace for the Colony. In 1897 he severed his connexion with the firm of Bewick, Moreing & Co. and commenced business as a Consulting Mining Engineer in Perth. After eleven years of unofficial geological work in West Australia Mr. Woodward, in 1906, rejoined the Government Geological Survey under Mr. A. Gibb Maitland, a post he continued to hold up to the time of his death, which occurred (after a brief illness) on February 7 last.[1]

On December 31, 1890, Mr. Woodward married Ellen Maude, the second daughter of the Hon. J. F. T. Hassell, of Albany; he leaves a widow and three sons, the second of whom has recently joined the Australian Army.

MISCELLANEOUS.

Geological Map of City of Dublin Area.

The Ordnance Survey has published, at the price of 3*s*., a Geological Map of Dublin, on the scale of six inches to one mile, prepared by the Geological Survey of Ireland (Department of Agriculture and Technical Instruction). It extends from Clontarf and Sandymount to Castleknock and Drimnagh, thus including the City, Phœnix Park, and a large residential district. The superficial deposits, boulder-clay, gravels of various types, and materials on the area intaken from the sea, are shown by colours, the underlying limestone rock appearing only in a few rare patches. Hence the map is of special service to architects and engineers, and to all who are concerned with house-sites and town-planning. The topographic basis is identical with Sheet 18 of the Ordnance Survey map of the County of Dublin, and hence a map of the city is provided on a large scale in addition to the geological information. Among the points of interest brought out on the map are the courses of the partially concealed streams that run into the Liffey on the southern side; the great plateau of boulder-clay that masks the old bank of the Liffey in the region of Phœnix Park; and several of the gravel mounds of the Greenhills esker, which have supplied so much material for roads and building purposes. The alterations, partly due to human and partly to marine agency, in the coastline at the west end of Dublin Bay, are well shown by the insertion, in red dotted lines, of the coast, as represented in a map by Bernard de Gomme, published in 1673. The district is described in detail in the illustrated Memoir of the Geological Survey on the country around Dublin (1903; price 3*s*.).

[1] For a fuller notice of H. P. Woodward's life and work see the Geological Magazine for September, 1897, pp. 385–8 (with a portrait).

No. 67. March, 1917.

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ORIGINAL ARTICLES.

I.—The Glacial Controversy in New Zealand.

By C. T. Trechmann, M.Sc., F.G.S.

THE controversy which has arisen in recent years in New Zealand regarding the problem of the Pleistocene glaciation of that country resolves itself into the two following main questions:—

1. Was there any glaciation in the North Island?
2. Was there an ice-sheet covering the South Island?

The discussion reached a culminating stage in the year 1909, when papers by Professors P. Marshall[1] and J. Park[2] appeared setting forth the two opposing views. These views have been further summarized more recently in general works dealing with the geology of New Zealand.

Professor Park[3] states that New Zealand was glaciated as far north as latitude 39°, an area which includes the southern half of the North Island and the whole of the South Island, where, he says, the ice reached not only the west coast but also the existing strand of the east coast.

Professor Marshall[4] declines to admit any evidence of glaciation in the North Island. He holds to the view that there was nothing in the nature of an ice-sheet in New Zealand, and that the glaciation of the South Island was a phenomenon confined to certain areas, in fact essentially an extension of the very restricted glaciers which exist at the present day. He speaks,[5] however, of the Taieri schistose conglomerate on the east coast of Otago, on which the supposed evidence of an ice-sheet largely rests, as a glacial moraine, though his remarks make it clear that he is in some doubt as to its true age and mode of occurrence.

Totally independent evidence from the botanical point of view against New Zealand having experienced in recent times an ice-sheet similar to that which covered parts of the northern hemisphere is published by Geo. M. Thomson.[6] The botanical evidence certainly

[1] "The Glaciation of New Zealand": Trans. N.Z. Inst., vol. xlii, pp. 334–48, 1909.

[2] "The Great Ice Age of New Zealand": Trans. N.Z. Inst., vol. xlii, pp. 589–612 and 575–588, 1909.

[3] *Geology of New Zealand*, 1910, p. 182.

[4] Ibid., 1912, p. 202.

[5] Ibid., 1912, p. 203.

[6] "Botanical Evidence against Recent Glaciation of New Zealand": Trans. N.Z. Inst., vol. xlii, pp. 348–53, 1909.

seems to carry great conviction, though I am not competent to offer any useful opinion on this matter.

Other New Zealand geologists appear to adopt an attitude of neutrality, or so far as they have expressed any opinion on the subject seem to lean towards the view that the glaciation was of a localized and not of a regional character.

The glacial or reputed glacial sections and boulders I have actually seen in New Zealand are comparatively few, but in so far as they affect the questions above-mentioned they are important and critical ones. The evidence of a general nature dealing with the two contending views has been so thoroughly put forward in the papers quoted that to go into it would merely be repeating what has already been written, so I shall confine myself to giving my own interpretation of the sections I visited.

Taking the question of the North Island first, Professor Park says in his *Geology of New Zealand*,[1] where he devotes many pages to a detailed description of the various sections, "In the Rangitikei watershed there is a glacial moraine of great extent composed of andesitic blocks torn from the higher slopes of the volcano Ruapehu and transported across the Rangitikei divide into the lower Hautapu valley. This conspicuous moraine sheet is spread over the denuded surface of marine clays of Pliocene age." He speaks of this as the Hautapu or older glacial drift and the Hautapu till.[2]

When I was in New Zealand in 1915 I heard that Professor Park had found one of these andesite boulders bearing striæ which placed its glacial origin beyond question. I mentioned this matter to him when I had the pleasure of meeting him, and he kindly gave me instructions as to where I could see the boulder. Professor Park has recently described this boulder in detail,[3] and gives an excellent photograph both of the whole mass and a nearer view showing the scratches on it.

This boulder bearing the scratches is of prime importance because it seems to me that the question of the glaciation of the North Island practically stands or falls with this boulder. If the scratches are not glacial the boulder is not glacial, and if this boulder is not glacial none of the others are glacial, and the chief evidence for a glaciation in the North Island fails.

I came away convinced that the scratches on the boulder are not glacial, and that they could have been and were caused by other means. I do not desire in any way to appear to take sides in this controversy, but with due respect to Professor Park's opinion I must say that I differ from him as regards the mode of origin of the striations on this boulder.

It is situated on the slope of a hill on the south side of the entrance of a railway tunnel south of Mangaweka station, several hundred feet above the deeply cut gorge of the Rangitikei River, and about 35 miles south-south-east of the summit of Ruapehu. It measures about $14 \times 8 \times 6$ feet, and must weigh about 35 tons.

[1] *Geology of New Zealand*, 1910, p. 183.
[2] Ibid., 1910, p. 205.
[3] Trans. N.Z. Inst., vol. xlviii (N.S.), pp. 135–7, 1915.

Professor Park says the whole of the under side of the boulder is scratched, but when I was there the vegetation round about it was very thick, but that portion of the under surface which I saw is clearly scratched. The surface of the boulder is much decomposed and weathered, and the little crystals composing the andesite can be rubbed off with the finger-nail, and in fact the surface can almost be scratched with the finger-nail, and scratches can easily be made on it with a knife blade.

The boulder rests on a slope and has evidently moved down from higher ground and must move further down in the future towards the river. The scratches could, in my belief, easily have been made by the movement of the boulder over gravelly soil or over other stones. Glacial scratches could not have survived the weathering to which the surface of this boulder has evidently been subjected.

It is true that on the summit of Ruapehu at the present day there exists a small glacier or ice-field at an altitude of from 7,000 to 9,000 feet, but there is nothing to show that it was ever more extensive or that Ruapehu had attained its present altitude in the Pleistocene period. Professor Marshall has pointed out that the slopes of the volcano show no evidence of former glaciation.

The question certainly arises as to how these large andesite boulders come to be scattered over the countryside in such numbers west and south-east of the parent volcano down the Hautapu Valley. Until the district has been accurately surveyed and their distribution mapped it is difficult to say what was the actual mode or direction of transport. They seem to be relics of former gravel or boulder beds which have survived and in some cases become isolated owing to their large size, but exactly at what period the beds were deposited cannot be asserted at present.

I may point out here that it rests with the upholders of a glacial origin for any beds to show that the phenomena cannot have originated in any other way than by glacial action. If their opponents cannot exactly explain the mode of origin of certain deposits it does not necessarily follow that the beds are glacial.

The deep and immature rock valleys seen in the southern part of the North Island, and especially round and near Wellington, are the very converse to what one would expect to find on the ice-sheet hypothesis. Under ice-sheet conditions they would have immediately been filled up with glacial debris.

Turning now to the South Island, the evidence that there was anything in the nature of an ice-sheet rests primarily on some deposits near the east coast of Otago. The largest of these is called the Taieri or Henley moraine. Professor Park describes it as the largest and most important pile of glacial drift in New Zealand. It forms the range of hills bounding the eastern side of the Taieri Plain, and rests against a ridge of mica-schist which separates that plain from the sea and rises to a height of 1,000 feet above sea-level. It extends from Allanton, 15 miles south of Dunedin, to a point in the Clutha Valley, a distance of about 25 miles. Material very similar to that which composes the Taieri "moraine" also forms the celebrated Blue Spur near Lawrence, which Professor Park also describes as glacial drift and which has long been worked for gold, and there are other outliers of a similar schistose conglomerate. In the Taieri Hills the more or less bedded material dips west at various angles. Professor Park states that the dip is towards the north-north-west for a distance of 2 miles at angles of 10 to 33 degrees. Its thickness is also very considerable, reaching apparently 1,500 feet. In addition to being tilted and faulted it has suffered prolonged erosion, and the deep valley of the Taieri River has been cut right through it.

The Dunedin–Invercargill railway skirts the western side of this chain of hills for over 20 miles, and it forms a very conspicuous feature of the topography.

If these hills were glacial—and when plotted on a map the outline of this rock certainly suggests in shape a great terminal moraine stretching parallel to the coast for many miles—then there must indeed have been a vast ice-sheet debouching from the Alpine region towards the east coast.

I am, however, convinced that they are not glacial. I visited the locality in company with Professor Marshall with a view to seeing this line of hills and of examining the sections exposed near Henley and in the gorge of the Taieri River which cuts through the supposed moraine. The material is almost, if not entirely, composed of schist; in places it is clearly current-bedded and sometimes very hard and compact. Masses of a very big size do not seem to occur. Professor Park says that pieces over 12 feet are exceptional, but the largest I saw were much smaller than that. He also adds that no striated boulders occur in it, and certainly I saw none.

I was struck with the dissimilarity of this deposit to any glacial moraine I had ever seen. Both this and the gold-bearing deposit of Blue Spur near Lawrence in Otago are deposits of post-Jurassic age and rest unconformably on the underlying mica-schist, but whether they are associated with the late Cretaceous or with the Tertiary periods of deposition must await further investigation.

New Zealand geologists should be able to trace these schistose conglomerates in some definite association with undoubted Cretaceous or Tertiary deposits which should settle the question. Sir James Hector and A. McKay associated the Taieri deposits with the brown-coal series of supposed early Tertiary age.

There is evidence that the Henley or Taieri conglomerate mass is faulted parallel to the Taieri basin, but the fault is nowhere seen. The material at Blue Spur is certainly faulted, and the faults are clearly revealed by the gold-sluicing operations. There are certainly recent fault dislocations in New Zealand, but those at Blue Spur appear to be of much earlier date than Pleistocene.

The removal of these schistose faulted conglomerates of Eastern Otago from the domain of glacial action removes also the chief evidence for any pre-Pleistocene glaciation. The traces of the Alpine glaciation are so fresh that any question of their being of Pliocene age is excluded.

Finally, as against the ice-sheet theory it may be mentioned that the two masses of Tertiary volcanic rocks of the Otago and Banks Peninsula on the east coast occupy a similar position relatively to the Alpine chain as the Cleveland Hills do to the centres of ice distribution in England or the Jura to the Swiss Alps. Had there ever been an ice-sheet in the South Island it must have extended at least to the foot of these elevated masses. Yet no trace of transported erratics is seen on the slopes of these hills nor on the plains between them and the Alpine range, nor have any glacial striæ been recorded on them.

Turning now to the Pleistocene glacial phenomena we find these splendidly developed along almost the whole length of the Alpine system of the South Island. The only place where I have had the opportunity of examining them at all closely is in the district of Lake Whakatipu. Here are all the features of a glaciation of the Alpine type splendidly displayed. There is the deep lake basin of Whakatipu, and how far this is due to the action of the ice affords the same opportunity for discussion as do the Swiss lakes. A fine arc-like terminal moraine spans the end of the lake at Kingston, having a length of 19 miles, and is cut through by the stream that drains the lake. At Bob's Cove, half-way up the lake, a fine series of erratics and striated surfaces is seen.

I came to the conclusion that there is no evidence of Pleistocene glaciation in the North Island, and that in the South Island the glaciation was of an Alpine and not of a regional type. The Pliocene and Pleistocene marine molluscan faunas show no evidence of the cold-water conditions such as occurs in countries that have experienced the conditions attendant upon the advance and retreat of an ice-sheet.

It remains for New Zealand geologists to determine whether there is in their Alps a succession of glacial deposits separated by inter-glacial episodes, or, as seems much more probable, that there was one glacial period whose deposits exhibit all the freshness shown by the remains of the Würm glaciation of the European Alps. Such seems to be the case with the glacial deposits I saw at Lake Whakatipu.

II.—The Base of the Chalk Zone of *Holaster planus* in the Isle of Wight.

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

STARTING with the bed labelled "*Bicavea* bed" by Rowe,[1] the following generalized section represents the downward sequence in the Isle of Wight.

		Feet.
1.	*Bicavea* bed.	
	Seam of grey marl ("Grey Marl").	
2.	Hard rough nodular chalk	8–10
	Seam of dark marl ("Black Marl").	
3.	Very hard lumpy chalk, containing a layer of green-coated nodules and passing in its lower 2 feet or so into smooth white chalk veined with marl	12–15
	Seam of marl.	
4.	Firm smooth white chalk in massive courses separated by seams of marl.	

[1] *The Zones of the White Chalk of the English Coast*, pt. v, p. 220.

The "*Bicavea* bed" is universally accepted as part of the zone of *Holaster planus*. The smooth white chalk in massive courses is the typical chalk of the zone of *Terebratulina lata*. Where between them is the boundary between the two zones to be drawn?

[It will be convenient to have short names for the two beds numbered 2 and 3 above. *Membranipora Vectensis*, Bryd., is a striking form very characteristic of Bed 2, and it will be called the "*Vectensis* bed". Bed 3 is described in all published sections as containing a layer of green-coated nodules, and I have therefore used these words; but in the Compton Bay section by far the most prominent layer is a continuous greenish-yellow stony layer, forming a sort of culminating point to the progressive hardening which has been going on both from above and below. The "layer of green-coated nodules" has been named by Rowe the "spurious Chalk Rock", and the bed will be called the "spurious Chalk Rock bed".]

For a long time before 1903 the "spurious Chalk Rock", or perhaps more accurately the "spurious Chalk Rock bed", was regarded as the direct equivalent of the Chalk Rock. Up to 1889 it figured as the top bed of the zone of *T. lata*, but in that year Strahan[1] included it in his "Upper Chalk", and so impliedly, if not directly, in the zone of *H. planus*.

In 1903 Jukes-Browne[2] drew the boundary between these zones at the "Grey Marl" on the grounds that *Holaster planus* and *Micraster Leskei* do not become abundant until we get above it, and that it was uncertain whether any specimen or fragment of *Micraster* had up to then been found below it. In 1908 these arguments were almost annihilated by Rowe, who recorded that *Holaster planus* was as common below the "Grey Marl" as above it, and that *Micraster* in the shape of *M. cor-bovis* was by no means rare below it—observations which entirely accord with my own. He transformed the observation about *Micraster Leskei* by the statement that it did not occur at all until above the "*Bicavea* bed", but he, too, adopted the conclusion that the base of the zone of *Holaster planus* was the "Grey Marl" on the grounds that *Echinocorys scutatus*, *Micraster Leskei*, and *Micraster præcursor* do not occur below it.[3] I have no reason to dispute these statements, but their force as arguments in the above connexion is quite another matter. On p. 221 we find that neither did *M. Leskei* or *M. præcursor* occur in the first bed *above* the "Grey Marl" (i.e. the "*Bicavea* bed"), and only one specimen of *E. scutatus* was found there. Now the "*Bicavea* bed" is unique in its quality of breaking up into blocks, which, owing to the presence of a marl seam both above it and below it, contain no element of any other bed, and whose horizon can be exactly determined owing to the ubiquity in it of *Bicavea rotula*. The result is that the surface of this bed which is available for study under the most favourable conditions is only limited by the number of blocks of it lying above wavewash on the falls of Culver Cliff and in Compton Bay, and its total area must be estimated in thousands of square

[1] *The Geology of the Isle of Wight* (Mem. Geol. Surv.), 1889.
[2] *The Cretaceous Rocks of Britain* (Mem. Geol. Surv.), pt. iii, 1904.
[3] Op. cit., p. 220.

yards. Under these circumstances the finding of a single specimen of *E. scutatus* is devoid of any serious significance, and when it figures as the sole reason for making a separation, not merely in zone but in stage, between the "*Bicavea* bed" and the "*Vectensis* bed", it is obviously so inadequate that it would be outweighed by the slenderest grounds for uniting these beds zonally. We are naturally led to ask whether there are any such grounds.

Accurate collecting from the "*Vectensis* bed" can only be carried on over the very limited area, probably not as much as 100 square yards all told, exposed *in situ*, as there is no outstanding feature by which fallen blocks from this bed can be certainly identified with it. I have only examined it once at Culver Cliff and twice at Compton Bay, but I have obtained from it besides other fossils the following significant ones:—

Holaster planus (abundant).
Pentacrinus (large ossicles in abundance).
Bourgueticrinus (joints in great abundance, many long and slender).
Lophidiaster ornatus (ossicles in abundance).
Crania Egnabergensis (several).
Lima Wintonensis (several).
Scalpellum maximum.
Polyzoa of twelve genera, most of which are represented by more than one species, including *Membranipora Vectensis* and *Bicavea rotula*.

Every item in this list is a strong link with the zone of *Holaster planus* and a strong distinction from the typical chalk of the zone of *T. lata* in the Isle of Wight at any rate. They must, of course, be taken quite strictly. A solitary specimen of *Lima Wintonensis* or *Crania Egnabergensis* would be unexpected without being startling in the typical *T. lata*-chalk of the Isle of Wight, but several specimens of either would compel a reconstruction of our ideas about that chalk. They are regular constituents of the *H. planus*-fauna, as also (at Compton Bay only) is *Scalpellum maximum*. *Lophidiaster ornatus*, which is fairly abundant in the Albian, is also known from the Chalk zones of *H. subglobosus*, *T. lata*, *H. planus*, and *Micraster cor-testudinarium*, but while it is abundant and very widespread in the zone of *H. planus* it is quite scarce in the other zones. Ossicles of *Pentacrinus* (to use the familiar name for convenience, not in ignorance of Dr. Bather's correction) are not of course *per se* peculiar to the zone of *H. planus*. I have them from every zone of the White Chalk, but the zone of *H. planus* is the only one beside that of *B. mucronata* in which they are not both scarce and small. Those of the "*Vectensis* bed" are as abundant as those of the *H. planus*-chalk and range freely up to ⅜ in. in diameter. Ossicles of *Bourgueticrinus* are not unknown in the typical *T. lata*-chalk of the Isle of Wight, but my experience is that they are scarce throughout and always short and stout in the upper part; in the lower part they may be long, but are never slender; those of the *H. planus*-zone agree absolutely with those of the "*Vectensis* bed". *Holaster planus* might occur in the typical *T. lata*-chalk of the Isle of Wight, but it would take a long time to find a second specimen, and an abundance of it is hardly imaginable. Finally, Polyzoa, numerous both in species and individuals, forbid any association of the "*Vectensis* bed" with the typical *T. lata*-chalk of the Isle of Wight. The presence of *Bicavea rotula* (paralleled inland by a specimen recorded at Arreton by Rowe himself[1]) should alone be enough to deter anyone from keeping this bed out of the zone of *H. planus* in order to attach it to the zone of *T. lata*; and you might search the typical *T. lata*-chalk of the Isle of Wight or any other South English district I am acquainted with for days without finding a single specimen of any Polyzoon, while Polyzoa are of course thoroughly characteristic and abundant features of the Senonian. The combined effect of these points seems to make an overwhelming case for uniting the "*Vectensis* bed" with the Senonian zone of *Holaster planus* in preference to the Turonian zone of *Terebratulina lata*.

Once the Senonian character of the "*Vectensis* bed" has been established the position of the "spurious Chalk Rock bed" becomes an open question. The bed itself is so hard and the area of it exposed *in situ* so small that palæontology is not likely to give much help. Its peculiar physical characters, striking as they are, cannot be relied upon for identifying fallen blocks, as there is, at Culver Cliff at any rate, a very similar bed in the zone of *M. cor-testudinarium*. It is to be noted, however, that *H. planus* is recorded from it, which is at any rate some argument in the Isle of Wight for attaching it to the zone of that fossil, and I have two specimens from it of the Polyzoon *Onychocella Lamarcki*, which is no ordinary fossil of the *T. lata*-chalk. The lithological evidence is all in favour of the same course. There is the widest difference between this bed and the typical *T. lata*-chalk, while there is a considerable affinity between it and the nodular and hard *H. planus*-chalk above. I come, therefore, to the conclusion that the "*Vectensis* bed" and the "spurious Chalk Rock bed" should both be placed in the zone of *Holaster planus*, and that the boundary between that zone and the zone of *T. lata* in the Isle of Wight should be drawn at the violent change from a long period of very uniform conditions of deposit which would seem to be marked by the appearance of the "spurious Chalk Rock bed".

It will be obvious that this conclusion cannot leave Dorset unaffected. The Dorset coast sections embracing the base of the zone of *H. planus* are, with the exception of the hopeless section in Durdle Cove, singularly inconvenient for access and very limited in area at the best. But it seems quite clear, from my own observations and those of Rowe,[2] that all along the Dorset coast a substantial thickness of typical *T. lata*-chalk is followed by a sequence for all practical purposes identical with that of the Isle of Wight; and the objections to associating either the relatively very fossiliferous chalk above the "spurious Chalk Rock bed" or the "spurious Chalk Rock bed" itself with the alien chalk below are of the same character as in the Isle of Wight, and, considering the nature of the exposures, equally strong.

The palæontological and lithological evidence can obviously in the Isle of Wight and apparently in Dorset be harmonized by taking the presence of *Holaster planus* as the test of the beginning of the zone

[1] Op. cit., p. 263.
[2] Op. cit., pt. ii, 1901.

of that fossil. If it is to be found at all in the typical *T. lata*-chalk it is a most exceptional occurrence, while it is found in the first bed above the typical *T. lata*-chalk (the "spurious Chalk Rock bed") and occurs freely in the next (the "*Vectensis* bed"). *Micraster* is a broken reed for this purpose. Even Rowe includes in the zone of *H. planus* 8 feet of chalk (the "*Bicavea* bed") in which he recognizes the absence of his test Micrasters for that zone, *M. Leskei* and *M. cor-testudinarium* (*præcursor* shape).

In conclusion I should like to point out that my statements as to the absence or rarity of certain fossils in the zone of *T. lata* in the Isle of Wight (or elsewhere) cannot be tested by reference to any lists which do, like those of Rowe & Jukes-Browne, or may, record the fossils of the "*Vectensis* bed" or corresponding beds under the zone of *T. lata*. I have, for my own part, relied on my general experience of typical *T. lata*-chalk in the South of England, supplemented by an examination made expressly for this purpose of the exposures at Compton Bay and Culver Cliff on occasions when they were in excellent condition.

III.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

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

III. Some variations in the Structure of the Apical System of *Holectypus*.

(PLATE XVI.)

1. Introduction.

Structural variation, unless due to injury or disease, may be regarded as a sign of racial health. The plasticity that allows or encourages deviation from the normal is an indication that the race is still young and vigorous, and that the deadening and ultimately fatal phase of stereotyped "perfection" has not been reached. The younger the race the more variable are even vital structures. It may be surmised that the several stages of race-life can be classified by the quantity and quality of variability shown. Indeed, variation, however induced or employed, is the determining force of evolution. Variants must therefore be considered as tentative and experimental efforts whose direction is parallel, or coincident, with the trend of evolution of the group. They can be used as indices of phylogeny that afford evidence of the ancestry, and also of the posterity, of their own and related stocks.

The recent work of R. T. Jackson on the relative positions of the ocular and genital plates in the apical systems of many Regular Echinoids, has brought to light abundant and convincing proof that a species consists of a "norm" surrounded by a series of regressive (or arrested) and progressive variants.[1] It has also been shown

[1] See especially "Phylogeny of the Echini" and "Studies of Jamaica Echini".

conclusively that the actual position of the norm between the extremes of variation differs in separate localities, resulting in local "varieties" which might be expected to extend their divergence until a distinct series of "species" was differentiated. A sufficient compilation of records would make possible a fairly confident prediction as to the main characters of these future species.

In the study of palæontological material there is often an opportunity to make actual observation of the ancestry and descendants of a particular species, and so it becomes possible to correlate the variations of that species with the known trend of evolution in the group to which it belongs. Conversely, an analysis of the variations may give suggestive evidence of relationships. I have been able to examine a considerable number of specimens of the common Inferior Oolite form, *Holectypus hemisphæricus*, from two localities in South-Western England. The results, in so far as they depend upon the structure of the apical system, seem sufficiently striking to be worthy of record. It must be remembered, however, that these results are based upon a study of some scores of individuals, while Jackson's are derived from hundreds or even thousands. The percentage calculations would be liable to considerable change when made from larger numbers.

In 1912 I showed, in this Magazine (Dec. V, Vol. IX, p. 8), the extreme diversity of structure met with in the apical system of the Holectypoida. Within the limits of the order there exists a record of the various methods whereby the readjustments, consequent on the backward migration of the periproct, were effected. The phylogenetically recent date of this disorganization rendered the apical system peculiarly sensitive to variation, and it was only in the later members of the order, and in descended stocks, that any fixity of structure was attained. The Bathonian species of *Holectypus*, though far in advance of *Plesiechinus* (in the repair of the apical system), are sufficiently near in time to the presumably Liassic origin of the order to exhibit much instability of apical structure. It would be interesting to examine a large series of *H. depressus* (the Inferior Oolite contemporary of *H. hemisphæricus*), so that a comparison could be made in this matter between the two strikingly distinct species. If any Cotteswold collectors who have a series of *H. depressus* would enable me to examine their specimens, I should be very grateful for the opportunity. Large numbers from one horizon and locality are required for useful results.

2. *Holectypus hemisphæricus.*

This well-known species is extremely abundant in the upper part of the Inferior Oolite (particularly in the *schlœnbachi*-hemera) of Dorsetshire. Its distribution is peculiar. As Richardson has shown, it is scarce, and often absent, in the Cotteswold district, flourishing only to the south of the Mendip axis. Its place in the more northerly region is taken by the small *H. depressus*, which, in its turn, is excessively rare in the south. In many parts of Dorsetshire *H. hemisphæricus* and *Pygorhytis ringens* vie with one another in abundance, and sometimes threaten the supremacy of the all-pervading *Terebratula* (*Sphæroidothyris*) "*sphæroidalis*".

The specimens of *H. hemisphæricus* are commonly small, averaging 2 cm. in diameter, and are remarkably uniform in size. It is easy, therefore, to collect plentiful material for a study of variation, without the complication of differences due to age. For the purposes of the present paper (which is only a preliminary note) specimens from two localities have been used, and no others are referred to, so as to avoid confusion. In a collection in the Manchester Museum there are twenty-two specimens (suitable for study) labelled "Broadwindsor"; all, apparently, from one quarry. In my own collection there were 167 specimens from a layer about one foot thick in a quarry on the side of the main road east of Bridport. Many of the latter series have been broken up or otherwise disposed of in the course of other work upon them, but examples of all observed types of variation have been retained.

Taking the 189 specimens together, the normal structure of the apical system (occurring in 55·5 per cent) is that represented by Pl. XVI, Fig. 2. But owing to the disparity in the numbers from the two localities, this combined percentage is misleading. The true relations of the "norms" and "variants" may be more satisfactorily expressed by means of the following table:—

Locality.	Total Number of Specimens.	Apical System as in				Aberrant Forms.	
		Pl. XVI, Fig. 1.		Pl. XVI, Fig. 2.			
		No.	%	No.	%	No.	%
Broadwindsor .	22	12	55	4	18	6	27
Bridport . .	167	32	19	101	61	34	20

From this table it appears that there are separate "norms" for the two localities, although the small number of the Broadwindsor specimens is unfortunate. Fifty-five per cent of the Broadwindsor forms have a type of apical system which is found in only 19 per cent of those from Bridport. And conversely 61 per cent of the Bridport examples possess a structure found in only 18 per cent of those from Broadwindsor. The percentage of aberrant types from both localities is surprisingly high.

(a) *The Broadwindsor norm.* (Pl. XVI, Fig. 1.)

The distinguishing character of this type of apical system depends upon the direction of the long axis of genital 2 (the madreporic plate). This axis is at an angle of between 80° and 75° to the antero-posterior axis of the test. The five genital plates are all subequal, but plate 1 is somewhat reduced. Owing to the direction of elongation of plate 2, plates 3 and 5 meet along a short transverse suture, so that plate 4 is not in contact with plate 2. The ocular plates are of considerable size, and are all approximately similar.

(b) *The Bridport norm.* (Pl. XVI, Fig. 2.)

Here the long axis of the madreporic genital is inclined at an angle of between 60° and 55° in relation to the antero-posterior axis. The genital plates are subequal, but plate 3 is somewhat reduced. Owing to the obliquely transverse extension of plate 2, plates 3 and 5 are widely separated from one another, and plate 4 meets plate 2 along a slightly curved suture of some length. The oculars are similar to those of the Broadwindsor type.

Among the twelve Broadwindsor specimens, and thirty-two Bridport specimens, that conform to Fig. 1, there are, of course, numerous trifling differences in the proportionate sizes of the plates and the angles of the sutures, but none of these differences affect the relation of the plates to one another. The same remark applies to the 4 and 101 specimens represented by Fig. 2. The two figures are copies of specimens that show the average characters for the respective types. Since the axis of the madreporic genital of *Plesiechinus* is almost parallel to the antero-posterior axis, and that of *Conulus* considerably inclined, the Bridport norm would seem to be progressive beyond the Broadwindsor type.

(c) *The aberrant forms.*

Beside the two alternative structures in the apical system above noted, there are three classes of variants that show more striking departures from the normal. These classes are illustrated by Pl. XVI, Figs. 3, 4, 5, and 6.

(1) *Variant* 1. (Pl. XVI, Fig. 3; cf. also Figs. 6, 7, and 8.)

This variation, which consists in the transgression of the madreporite on to genital 3, is by far the commonest type of abnormality in the series examined, and among other Holectypoids as well. Of the six aberrants from Broadwindsor five possess this character; one of them (Fig. 6) combining with it a different type of variation. Of the thirty-four aberrants from Bridport, no fewer than thirty-two possess a similar character. The five Broadwindsor specimens are all "norms" for their locality as regards the relations of the genital plates, but, as a comparison of Figs. 1 and 3 will show, the proportions of the plates are various. Thirty of the Bridport specimens have the "Bridport norm" in plate relations, the other two being like those from Broadwindsor.

I have not seen any specimens of *H. hemisphæricus* in which the madreporic perforations extend on to any other plate than genital 3. Variants of this character, often carried to a further degree, are by no means uncommon in *Conulus* (Pl. XVI, Fig. 8). In the specimen figured all four genital plates are perforated by the madreporite, but it is only on plate 3 (of the abnormal ones) that the pores are at all abundant.

In *Discoides* the extension of the madreporite on to all five genital plates is a generic character (Pl. XVI, Fig. 7). The variants of *Holectypus* of the type under consideration may then be considered to be progressive in the *Discoides* direction, while the similar variants in *Conulus* might be called "parallel variants", on the supposition that there is no direct phyletic sequence between *Conulus* and *Discoides*.

(2) *Variant* 2. (Pl. XVI, Figs. 4 and 5; cf. also Figs. 6 and 9.)

One specimen from Broadwindsor (Fig. 5) and two from Bridport (Fig. 4) show the development of a supernumerary plate more or less midway between genitals 2 and 5. In both the Bridport forms this is small and pentagonal, having sutural connexion with all the genitals except plate 4. (Both specimens have the "Broadwindsor" arrangement of the genital plates.) In the Broadwindsor specimen the supernumerary is large and hexagonal, and, being in contact with all five genitals, acts as a kind of "centrale". There is no evidence to prove that this included plate is not really genital 5, while the plate in the posterior region is the additional one; but it seems more reasonable to suppose that the appearances are not deceptive, and that the internal plate is actually the supernumerary.

Additional internal plates within the true cycles of the apical system occur in the Calycina among Regular, and in some of the *Clypeus–Nucleolites* series of the Irregular, Echinoids. This distribution of supernumeraries opens up an interesting speculation when applied to the variants under notice. *Acrosalenia* is an ancient, and in most respects, primitive member of the Diademoida (Centrechinoida), and may well have originated collaterally with the Holectypoids in Liassic times, even if it is not on their line of descent. So that a comparison of the aberrant *Holectypus* with *Acrosalenia* would class the variation in the former as either arrested (or regressive) or perhaps "arrested parallel". In the case of "*Nucleolites*" (as illustrated by "*N.*" *orbicularis* (Pl. XVI, Fig. 9), a considerable number of more or less symmetrically placed supernumeraries occurs posteriorly to the large madreporic genital. In Fig. 9, as I interpret it, plate *c* (the most posterior) represents genital 5, and either *b* or *a* might be correlated with the additional plate in *Holectypus*. In view of the fairly certain primitiveness of *Holectypus*, and the equally probable lack of direct sequence from that genus to the Nucleolitidæ, a comparison of the two would class the variant as an imperfectly "progressive parallel". This comparison will appear less far-fetched when the next section has been read.

(3) *Variant* 3. (Pl. XVI, Fig. 6; cf. also Figs. 8 and 9.)

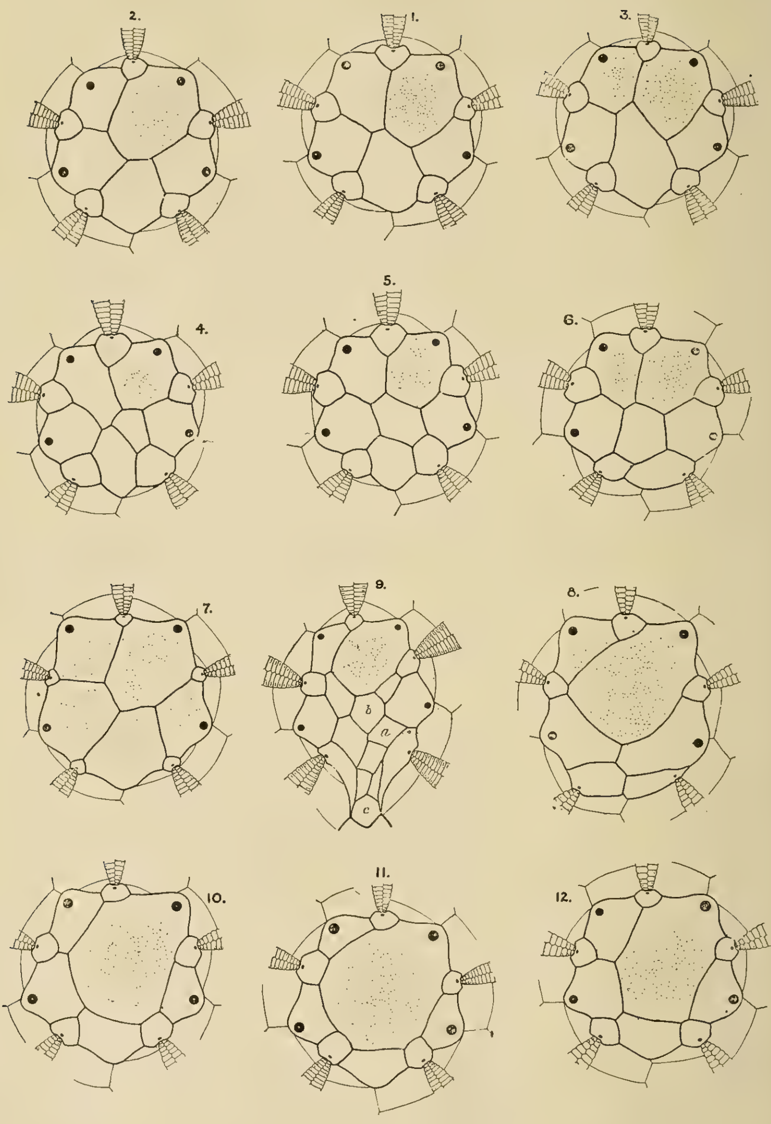
This solitary specimen from Broadwindsor shows a very striking abnormality. In the first place, it possesses the characters of variant 1, in that the madreporite is partly situated on genital 3. There is a "centrale"-like, hexagonal, imperforate plate a little behind the centre of the system, approximately similar in area to the two genitals (1 and 4) that flank it. Behind this included plate the two posterior oculars (I and V) meet. Both are enlarged and distorted in shape, but plate 1 is by far the larger of the two. There is thus no posterior genital (5); at least, as concerns the margin of the system. At first I was of the opinion that the included hexagonal plate was actually the fifth genital shifted anteriorly. But in view of the structures observed in variant 2, I now incline to the belief that the included plate is a supernumerary, and that genital 5 is wanting. If this is a correct interpretation of the specimen, it would prove to be similar to variant 2 in this respect as compared with *Acrosalenia* or "*Nucleolites*". On comparing oculars I and V in Figs. 6 and 9, a certain resemblance in their distorted shape and increased length is seen. In this respect also the *Holectypus* variant can be considered as "progressively parallel" to the "*Nucleolites*" norm.

A comparison between Figs. 6 and 8 (*Conulus*) is perhaps more satisfactory. The generic character of the *Conulus* apical system is the absence of the fifth genital and the consequent meeting of the posterior oculars, I and V. It is seen that in both figures these oculars are much enlarged. Although in the *Holectypus*, ocular I is the larger of the two, while the reverse is the case in the *Conulus*, the discrepancy is more apparent than real. Other specimens of *Conulus* (both *C. subrotundus* and *C. albogalerus*) have ocular I larger than ocular V. The less usual type was chosen for figuring because of its possession of the characters of variant 1. It will be readily seen that if the supernumerary plate in the *Holectypus* were removed the consequent readjustments would bring genitals 1 and 4 into contact (as they are in *Conulus*); and a very slight alteration in the dimensions of genital 2 would produce an almost exact similarity between the two systems. When it is realized that in *Holectypus depressus* (see Fig. 11) genital 2 may be in contact with ocular IV (as is the case in *Conulus*), the correspondence between the two structures becomes more obvious.

Thus while the included supernumerary plate and the posterior oculars (in the variant illustrated in Fig. 6) show an inclination towards the *Nucleolites* character, the absence of genital 5 and the meeting of oculars I and V indicate a very definite "progressive" variation towards *Conulus*. Whatever may be the ancestry of the last-named genus, its line of descent cannot have been remote from that of *Holectypus*.

3. *Holectypus depressus* (Cornbrash). (Pl. XVI, Figs. 10 and 11.)

Although I have not enough specimens of this large and abundant species (which is surely specifically distinct from the small Inferior Oolite form of the same name), there are two types of apical system shown in the few examples at my disposal. The madreporic genital (2) is always large in this species, and the madreporite occupies a prominent position in the centre of the system. In six specimens, ranging in diameter from 2 to 5 cm., the plates are arranged as in Fig. 10. Using a terminology analogous to that employed by Jackson for Regular Echinoids, this type may be said to have oculars I, II, and III "insert" (to the madreporite instead of to the periproct), and oculars IV and V "exsert". (By a similar argument *H. hemisphæricus* has only oculars II and III "insert".) But in one medium-sized specimen (Fig. 11), with a diameter of about 3–5 cm., genital 2 is so enormously expanded that the remaining genitals are much reduced in size, and all five oculars are "insert", being in contact with the madreporic plate. The specimens are



H. L. H., del.

NORMAL AND ABNORMAL APICAL SYSTEMS OF *HOLECTYPUS* AND OTHER GENERA.

all from the same locality, and those of the remaining six that approximate to the size of this specimen have the characters of Fig. 10. So there are indications that another series of variants could be traced in this species. The original of Fig. 11 cannot be regarded as progressive towards the Corallian species (*H. oblongus*, Fig. 12), for in six specimens of that form, from Upware, the ocular "insertion" is identical with that of the Cornbrash "norm". The contact between genital 2 and ocular IV in this specimen suggests comparison with the conditions in the apical system of *Conulus* (Fig. 8), but that feature, and the large size of the madreporic genital (not a variant character) are the only points of resemblance between the two.

4. Summary.

The characters of the apical system of a series of *Holectypus hemisphæricus* from the same horizon at two localities in Dorsetshire are analysed and described. It is found that the average relations of the plates of the system are different at the two localities, although certain numbers of identical forms occur at both. Out of 189 specimens (from both localities), 40 show serious departures from the normal type. These abnormalities are of three classes. One, the most prevalent, consists in the presence of madreporic pores on genital 3, in addition to the normal perforation of genital 2. This is regarded as a "progressive variant" in the direction of *Discoides*. The second, occurring in three specimens, consists in the interpolation of a supernumerary plate within the system. It is suggested that this may be either a "regressive variant" towards *Acrosalenia*, or a "progressive variant" towards *Nucleolites* (as illustrated by *N. orbicularis*). In neither case would this variation coincide with actual phyletic sequence, so that it is styled "parallel variation". The third type of variant, seen in one specimen only, combines both the first and second types, and in addition shows an absence of genital 5 and a corresponding increase in the size of the posterior oculars, which meet round the back of the system. The variation in this specimen is interpreted as being "progressive" towards *Discoides*, "parallel progressive" or "regressive" towards *Nucleolites* or *Acrosalenia* respectively, and "progressive" towards *Conulus*. There are indications of a different series of variants in the *Holectypus depressus* from the Cornbrash. The high percentage of variation in the composition of the apical system of *Holectypus* is regarded as an indication of the evolutional activity of the genus, and of its near approximation in time and phylogeny to the common origin of many of the groups of Irregular Echinoids.

EXPLANATION OF PLATE XVI.

All figures are considerably magnified, and are brought to a uniform size for convenience of comparison. All are viewed from the outside of the test, so that the numbering of the plates is in an anti-clockwise direction.

Fig.

1. *Holectypus hemisphæricus*. Broadwindsor. The normal apical system for this locality. Genitals 3 and 5 in contact.
2. ,, ,, Bridport. The normal apical system for this locality. Genitals 3 and 5 separated by 2.

Fig.			
3.	*Holectypus hemisphæricus.*	Broadwindsor.	Variant 1.
4.	,, ,,	Bridport.	Variant 2.
5.	,, ,,	Broadwindsor.	Variant 2.
6.	,, ,,	Broadwindsor.	Variant 3.
7.	*Discoides cylindricus.*	Wallingford.	Normal apical system.
8.	*Conulus subrotundus.*	Reigate.	Cf. variant 1.
9.	*Nucleolites orbicularis.*	Rushden.	? Normal apical system.
10.	*Holectypus depressus.*	Rushden.	Oculars I, II, and III "insert".
11.	,, ,,	Same locality.	All oculars "insert".
12.	,, *oblongus.*	Upware.	Normal apical system.

IV.—On some new Cenomanian and Turonian Cheilostome Polyzoa.

By W. D. Lang, M.A.

(By permission of the Trustees of the British Museum.)

(PLATE XVII.)

Hapsidopora, new genus.

(ἡ ἀψίς, 'an arch,' in reference to the hoop formed proximally to the aperture.)

Diagnosis.—Asty incrusting, uniserial, with bilateral and unilateral branching; œcia dimorphic; normal œcia with short caudæ or without caudæ; pyriform; termen a complete, high, narrow, oval ridge with few small spines on its circumference and, at the proximal-lateral corners of the aperture, a pair of stout spines which sometimes, if not always, bend towards one another and fuse in the middle line; apparently there are no spines around the distal end of the aperture; extra-terminal front-wall well-developed proximally, and arched; intra-terminal front-wall a wide, depressed lamina; aperture oval, sub-quadrate, somewhat constricted laterally; avicularia small, one, or a pair, placed laterally and somewhat distally with regard to each aperture, rather abruptly pointed with the distal ends curved towards the aperture they encompass; ovicells hyperstomial.

Genotype.—*Hapsidopora arcuata*, n.sp.

Remarks.—It is noteworthy that the terminal ring of *Hapsidopora* is complete proximally, and not smoothed away as in so many other forms with a wide lamina.

Key to the genus *Hapsidopora*.

A. Pair of spines at the proximal-lateral corners of aperture not so stout, and the terminal spines proximal to these larger than in *H. arcuata* . . . . 1. *H. harmeri*.

B. Pair of spines at the proximal-lateral corners of the aperture very stout and arching over, fuse with one another in the mid-line; terminal spines proximal to these smaller than in *H. harmeri* . . . . . . 2. *H. arcuata*.

HAPSIDOPORA HARMERI, n.sp. Pl. XVII, figs. 1 and 2.

(As a mark of respect to my colleague and former teacher, Dr. S. F. Harmer.)

Diagnosis.—*Hapsidopora* with comparatively large terminal spines, and the spines in the proximal-lateral corners of the aperture smaller than in *H. arcuata*; the terminal ring makes a narrower ellipse; the avicularia are slightly slenderer than in *H. arcuata*.

Type-specimen.—British Museum specimen no. D. 21673; Cenomanian, Chalk Marl, 20 ft. from the base; Cambridge; F. Möckler Coll.

HAPSIDOPORA ARCUATA, n.sp. Pl. XVII, figs. 3 and 4.

(*Arcuatus*, 'arched,' in reference to the hoop-like structure proximal to the aperture.)

Diagnosis.—*Hapsidopora* with very small terminal spines and a very stout pair of spines at the proximal-lateral corners of the aperture; the terminal ring makes a wider ellipse; the avicularia are somewhat stouter than in *H. harmeri*.

Type-specimen.—British Museum specimen no. D. 22871; Cenomanian, Chalk Marl, 20 ft. from base; Cambridge; F. Möckler Coll.

TYLOPORA, new genus.

(ὁ τύλος, 'a knob,' in reference to the beaded termen.)

Diagnosis.—Asty incrusting, pauciserial and branched; at each branch an uniserial stage is nearly or quite resumed, though sometimes a lateral bud from an œcium of one branch curves away and joins the other branch; œcia dimorphic, with unilateral budding, elliptical with tapering proximal ends, but no caudæ; termen plain or with minute spines, to beaded; extra-terminal front-wall present only at the extreme proximal end of the œcium; intra-terminal front-wall a wide, depressed, proximal lamina prolonged on each side in lateral terminal bevels; aperture circular to oval; renewed œcia abundant; avicularia small, blunt, generally one, sometimes a pair placed distally and somewhat laterally to each œcium.

Genotype.—*Tylopora lorea*, n.sp.

Key to the genus *Tylopora*.

A. Termen plain, or with minute spines . . *T. ligatrix*.
B. Termen beaded.
  1. Œcia shorter (about ·6 mm) and blunter distally . . . . . . *T. rowei*.
  2. Œcia longer (about ·8 mm) and more pointed distally . . . . . *T. lorea*.

TYLOPORA LIGATRIX, n.sp. Pl. XVII, figs. 5 and 6.

(*Ligator*, 'a binder,' invented from *ligare* 'to bind', from the strap-shaped asty.)

Diagnosis.—*Tylopora* with a plain termen, or, if spines are present, these are exceedingly small.

Type-specimen.—British Museum specimen no. D. 29205; incrusting *Conulus subrotundus* Leske. [Turonian, zone of *R. cuvieri*]; Burham, north-west of Maidstone, Kent. Coll. Hon. R. Marsham.

Tylopora rowei, n.sp. Pl. XVII, figs. 7 and 8.

(As a mark of regard to Dr. A. W. Rowe, who kindly lent me the type-specimen for description.)

Diagnosis.—*Tylopora* with a beaded termen, and short (about ·6 mm. long) rather blunt œcia.

Type-specimen.—In the collection of Dr. Rowe of Margate; incrusting *Infulaster excentricus* (S. Woodward); Turonian, zone of *Terebratulina*; Norfolk.

Tylopora lorea, n sp. Pl. XVII, figs. 9, 10 and 11.

(*Loreus*, 'made of thongs,' in allusion to the strap-shaped asty.)

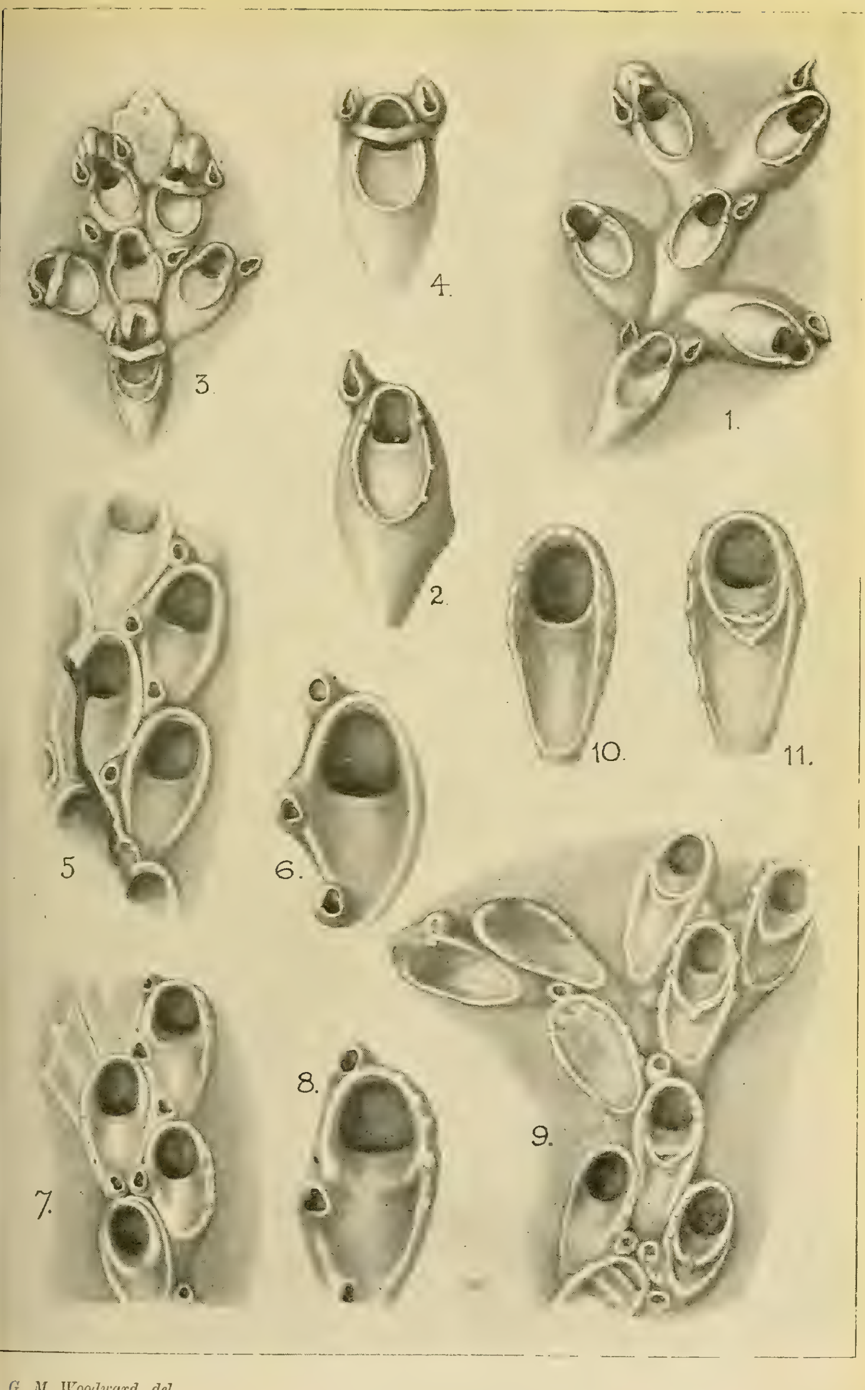
Diagnosis.—*Tylopora* with a beaded termen, and longer (about ·8 mm.) and rather more pointed œcia.

Type-specimen.—British Museum specimen no. D. 15389; Turonian, zone of *Holaster planus*; Church Top Pit, South Elkington, west of Louth, Lincs; Coll. C. S. Carter.

EXPLANATION OF PLATE XVII.

Fig.

1. *Hapsidopora harmeri*, n.sp. Portion of the type-specimen, showing bilateral and unilateral branching. × about 34 diameters. British Museum specimen no. D. 21673. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
2. *Hapsidopora harmeri*, n.sp. A single œcium—the distal-most—of the part of the type-specimen represented in fig. 1. × about 50 diameters.
3. *Hapsidopora arcuata*, n.sp. Portion of the type-specimen, showing bilateral and unilateral branching. The most proximal œcium is a renewed œcium. × about 26 diameters. British Museum specimen no. D. 22871. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
4. *Hapsidopora arcuata*, n.sp. A single œcium from another part of the type-specimen than that represented in fig. 3. × about 40 diameters.
5. *Tylopora ligatrix*, n.sp. Portion of the type-specimen. × about 26 diameters. British Museum specimen no. D. 29205. [Turonian, zone of *Rhynchonella cuvieri*.] Burham, Kent. Hon. R. Marsham Collection.
6. *Tylopora ligatrix*, n.sp. A single œcium—the most distal on the right-hand side—of the part of the type-specimen represented in fig. 5. × about 40 diameters.
7. *Tylopora rowei*, n.sp. Portion of the type-specimen. × about 26 diameters. Turonian, zone of *Terebratulina*. Norfolk. In the collection of Dr. A. W. Rowe.
8. *Tylopora rowei*, n.sp. A single œcium—the most distal on the right-hand side—of the part of the type-specimen represented in fig. 7. × about 40 diameters.
9. *Tylopora lorea*, n.sp. Portion of the type-specimen, showing a branch. Five of the œcia are renewed œcia, and four are closed œcia; the remaining œcium (on the left, proximally) is normal. × about 26 diameters. British Museum specimen no. D. 15389; Turonian, zone of *Holaster planus*. South Elkington, Lincs. C. S. Carter Collection.
10. *Tylopora lorea*, n.sp. A single œcium, the only normal one in the portion of the type-specimen represented in fig. 9, namely that on the left-hand side and proximally situated. × about 40 diameters.
11. *Tylopora lorea*, n.sp. A single renewed œcium—just proximal to the middle—of the part of the type-specimen represented in fig. 9. × about 40 diameters.



G. M. Woodward, del.

HAPSIDOPORA and TYLOPORA.

NOTICES OF MEMOIRS.

I.—The Conchological Features of the Lenham Sandstones of Kent, and their Stratigraphical Importance.[1] By R. Bullen Newton, F.G.S., of the British Museum (Natural History).

Part I.

At various points along the summit of the chalk escarpment forming the North Downs of Kent and Surrey and extending from Paddlesworth near Folkestone to Lenham near Maidstone, and thence to Netley Heath between Guildford and Dorking—a distance east and west of about seventy miles—there occur in pockets, cavities, or "pipes" of the Chalk formation, certain scattered masses of a reddish ferruginous sandstone at considerable altitudes above sea-level; at Paddlesworth this sandstone has been observed at 600 feet; at Lenham 680 feet; while at Netley Heath it is found at a height of between 570 and 600 feet. Sandstones of corresponding age are met with in France particularly on the hills between Calais and Boulogne, and on Cassel Hill near Dunkirk at 515 feet; they also occur at Louvain (200 feet) and Diest, both in Belgium, the beds of the latter locality having yielded fossiliferous remains bearing a resemblance to the Lenham fauna, although often differing in specific characters.

The more important of these sandstone deposits, so far as this country is concerned, are those found on the Lenham Downs, as they contain the remains of a marine fauna, chiefly of conchological interest, whereas the beds of other districts are generally unfossiliferous, although it should be mentioned that a few Mollusca of rather uncertain character have been obtained from both Paddlesworth and Netley Heath.

The fossils known in the various museum collections have been mostly obtained from a large disused chalk quarry situated about half a mile to the north of Lenham, of which an excellent sketch may be consulted in Mr. Reid's "Pliocene" memoir of 1890, showing the vertical positions assumed by the fossiliferous sandstone pipes seen in the limestone exposure. It has been generally recognized that such deposits represent the remnants of a marine Tertiary formation belonging to early Pliocene times, although my own investigations have led to somewhat different results, and I am more inclined to refer them to the latest division of the Miocene period.

The organisms occur as casts and cavities in the sandstone, and are frequently in a fragmentary condition, rendering their determination extremely difficult. The walls of the cavities, however, often retain sculpture characters, so that it is possible by the aid of wax impressions to obtain reliable evidence as to external details which

[1] We have just received in a connected form the complete text of Mr. R. B. Newton's valuable memoir "On the Conchological Features of the Lenham Sandstones of Kent, and their stratigraphical importance". This paper formed the subject of his Presidential Address to the Conchological Society of Great Britain and Ireland at Manchester, on October 16, 1915, and was afterwards printed in four parts in the *Journal of Conchology*, vol. xv, 1916–17, making 64 pages, with 4 plates of Mollusca. With the author's kind permission we give an abridged notice.

may be safely used for purposes of identification. To Mr. Clement Reid, F.R.S., we are mainly indebted for most of our later knowledge of the Lenham fauna, his researches forming part of the "Pliocene" memoir before mentioned. At that time Mr. Reid had obtained an important series of fossils from the Lenham Beds for the Museum of Practical Geology, which, after being determined, were systematically referred to in the memoir. In order to facilitate my studies on this subject and to enable me to determine certain collections of similar fossils in the British Museum, especially that formed by Mr. Graham Wallas, I was very kindly allowed to loan this valuable type collection made by Mr. Reid. During my studies in this direction it has been necessary to introduce a certain amount of revision, both among the genera and species as laid down in Mr. Reid's memoir. The larger amount of material available at the present time has also resulted in the determination of additional species, so that the shells are regarded as numbering 77 species, which include 1 Scaphopod, 32 Gastropods, 43 Pelecypods, and 1 Brachiopod, whereas Mr. Reid's conchological list embraced 65 species, consisting of 1 Scaphopod, 27 Gastropods, 36 Pelecypods, and 1 Brachiopod. Among the 32 Gastropods now recognized, a new species has been described under the designation of *Ringiculella lenhamensis*. In view of the fact that no figures have yet been published of Lenham fossils, I have had prepared some photographs of the more important shell-remains, which on account of their reddish-brown colour and their more or less obscure character have not been particularly successful; yet it is hoped they may serve a useful purpose in stimulating the interest of the student who desires to pursue further researches on the conchology of these little-known beds.

To complete the Lenham fauna I have here briefly introduced a list of the other organic remains which are found associated with the shells:—

PISCES.
 Selachian vertebræ and a palatal plate as determined by Dr. A. S. Woodward. Coll. B.M.[1] (Graham Wallas).

POLYZOA.
 Fascicularia aurantium, M. Edwards. Coll. M.P.G., No. 398.
 Cupularia canariensis, Busk. Coll. M.P.G., No. 399. B.M. (Graham Wallas).

ANNELIDA.
 Ditrupa subulata, Deshayes, sp. Coll. M.P.G., No. 395.

CRUSTACEA.
 [A decapod claw.] Coll. B.M. (Graham Wallas).
 Balanus. Coll. M.P.G., No. 396.

ECHINODERMATA.
 Temnechinus (?). Coll. B.M. (Graham Wallas).
 Echinus woodwardi, Desor. Coll. M.P.G., No. 394. B.M. (Prestwich and Graham Wallas).
 Dorocidaris papillata, Leske, sp. Coll. B.M. (Prestwich).

ACTINOZOA.
 Trochocyathus (?). Coll. B.M. (Graham Wallas).

[1] The author desires to acknowledge his thanks to the authorities of the Museum of Practical Geology, and particularly to Mr. H. A. Allen, F.G.S., of that institution, for allowing him access to the "Reid" Collection. The letters B.M. and M.P.G. throughout this work apply respectively to the British Museum and the Museum of Practical Geology.

In addition to these organisms the Lenham sandstones occasionally exhibit impressions of the spines of *Cidaris clavigera*, König, and remains of *Inoceramus*-shell associated with the sponge *Cliona*, all of which belong to the Chalk (Senonian) formation, and are consequently of derivative origin. No trace has been discovered in these beds of any fossils which could possibly have been derived from Eocene rocks.

Bibliography (1857–1915).[1]

The history of the Lenham deposits and their fauna was commenced by the late Sir Joseph Prestwich in 1857,[2] when reporting the discovery by W. Harris and Rupert Jones of certain "blocks of gritty ferruginous sandstone, full of casts of shells", in some sand-pipes in the Chalk at Lenham, eight miles east of Maidstone, which they regarded as belonging to the basement-bed of the London Clay. Prestwich was familiar with similar sandstones occurring at Paddlesworth, near Folkestone, at a height of about 600 feet above sea-level, and at Vigo Hill near Otford in Kent, mentioning likewise that they were to be found in scattered fragments along the summit of the North Downs, extending from near Folkestone to Dorking in Surrey; but from the fossils he considered that the sandstones were of Lower Crag age, on account of the presence of a *Terebratula* resembling *T. grandis*, several species of *Astarte*, and a large *Lutraria*-like shell; this view being also shared by Searles Wood, who had examined the fossil remains, and recognized the importance of the occurrence of a *Pyrula* and an *Emarginula* as supporting that horizon. Prestwich also noted that beds of similar structure were present on the hills between Calais and Boulogne, at Cassel Hill near Dunkirk, and at Louvain and Diest in Belgium, besides thinking it possible that such sandstones were connected with the Carentan beds of Normandy.

In the following year Prestwich[3] again returned to the subject, aided by Searles Wood. He noticed that many of the species found at Lenham were of southern origin, thus confirming his previous ideas that the deposits were of Lower or Coralline Crag age. His determinations of the shells included the following forms:—

Scaphopoda.
Dentalium costata (?).

Gastropoda.
Emarginula reticulata (?).
Nassa prismatica (?).
Scalaria subulata (?).
Pyrula.
Trochus.
Natica.
Rissoa (?).
Phorus, related to *Trochus cumularis*, Brong.

[1] The conchological determinations mentioned in the following memoirs are those of the authors themselves, without any attempt at a rectification of the nomenclature.

[2] "On some Fossiliferous Ironstone occurring on the North Downs": Quart. Journ. Geol. Soc., vol. xiii, pp. 212, 213, 1857.

[3] "On the Age of some Sands and Iron-Sandstones on the North Downs"; with a Note on the Fossils, by S. V. Wood: Quart. Journ. Geol. Soc., vol. xiv, pp. 322–35, 1858.

PELECYPODA.
- *Arca lactea* (?).
- *Pecten avicula* (?) and *P. bruei.*
- *Modiola modiola* (?).
- *Pectunculus glycymeris* (?).
- *Nucula nucleus* (?).
- *N. depressa*, Nyst.
- *Leda lanceolata* and *L. myalis* (?).
- *Astarte digitaria*, *A. pygmæa*, *A. compressa* (?), *A. omalii* (?).
- *Cardium* (with spines) and *C. edule.*
- *Cytherea rudis* (?).
- *Tapes perovalis.*
- *Lutraria elliptica.*
- *Crassatella concentrica* (?), Duj.
- *Tellina donacina* (?) or *Donax.*
- *Mactra triangulata* (?).
- *Cardita*, *Lucina* or *Diplodonta*, *Kellia* or *Lepton*, *Isocardia.*
- *Venus* (?), *Anatina*, *Panopœa* (?).

BRACHIOPODA.
- *Terebratula grandis* (?).

In the same memoir Prestwich referred to the occurrence of similar ferruginous sandstones to those at Lenham on the chalk downs between Calais and Boulogne, and at Cassel Hill in French Flanders, 515 feet above the sea, overlying the Calcaire Grossier series. It was mentioned that such beds, although without fossils, had been determined by Dumont and Lyell as equivalent to the Diestian Sands of Belgium, which they classed with the English Crag, because the same sands had been found at Louvain overlying the Limburg and Bolderberg strata, containing impressions of shells of *Terebratula grandis*, *Solen ensis*, and *Syndosmya prismatica*, besides thirteen genera of indeterminable species. In a further reference to the Lenham Mollusca, Searles Wood [1] mentioned that the *Pyrula* and *Pectunculus* resembled certain sandstone casts from the Red Crag (Box-stone specimens), although a closer determination was not possible from their peculiar preservation.

Lyell [2] recognized the Lenham Beds as of Upper Miocene or Falunian age, and similar to the Diestian Sands of Belgium, and, moreover, probably older than the Coralline Crag.

He had traced the Diestian beds, which "abound in green grains", from Diest by Louvain and Oudenarde to Cassel in French Flanders and capping the hills of those places—away to the English Downs near Folkestone, and appearing at such places as Paddlesworth, Lenham near Maidstone, etc. He referred to the occurrence in those beds of *Terebratula grandis*, casts of *Astarte*, *Pyrula*, *Emarginula*, which were all common to the British Crag, the first-named being specially characteristic of the Belgian Diestian.

As a result of an examination of the Prestwich Collection and that of the Geological Survey, Von Koenen [3] was of opinion that Lyell was wrong in his estimate of a Miocene age for the iron-sandstones of Kent, he regarding them as Pliocene because he considered they contained characteristic shells of the Upper Crag.

Mr. Whitaker [4] next gave his opinion on the age of the Lenham fauna, assisted by Gwyn Jeffreys in connexion with the molluscan

[1] "On the Extraneous Fossils of the Red Crag": Quart. Journ. Geol. Soc., vol. xv, pp. 32–45, 1859.

[2] *Elements of Geology*, 6th ed., pp. 233, 368, 1865.

[3] "Die Fauna der Unter-oligocänen Tertiärschichten von Helmstadt bei Braunschweig": Zeitsch. Deutsch. Geol. Ges., vol. xvii, p. 461, 1865.

[4] "On the Lower London Tertiaries of Kent": Quart. Journ. Geol. Soc., vol. xxii, p. 430, 1866.

determinations. Their results suggested an Eocene horizon, because among the fossils was identified a *Phorus* like *P. agglutinans*, *Cyrena cuneiformis*, and a small *Nucula* like *N. minor*.

Bristow [1] supported the Eocene age theory for the Paddlesworth ferruginous sands, which are unfossiliferous, and suggested that they belonged to the Woolwich and Reading series. In a postscript to this paper we are informed that the palæontologist W. H. Baily had examined Lenham fossils and pronounced them to be of London Clay origin.

In a later paper Von Koenen [2] regarded the ferruginous sandstones of Kent as corresponding with the Red Crag on account of the presence more particularly of *Arca lactea*, *Scalaria foliacea*, *Emarginula fissura*, and *Terebratula grandis*.

Writing on the "Box-stones" of East Anglia, Sir Ray Lankester [3] thought it very probable they were of the same age as the Lenham Sandstones; the former he considered as belonging to the Diestian series of Belgium, and approximately equivalent to the so-called Black Crag of Antwerp. The Belgian geologist Mourlon [4] next recognized that the "Sables de Diest" occurred on the North Downs of Kent, between Folkestone and Dorking, Paddlesworth, and Lenham near Maidstone, as first indicated by Prestwich and Lyell. Messrs. Cogels and O. Van Ertborn [5] alluded to Lyell's statement as to the abundant occurrence of *Terebratula grandis* in the ironstones of the North Downs, which was also found in the Diestian beds of Belgium, this horizon being considered of Lower Pliocene age and not Miocene as understood by Lyell.

A great advance in our knowledge of the Lenham deposits was next made by Mr. Clement Reid,[6] who regarded the beds as Older Pliocene of Coralline Crag age, and equivalent to the Lower Crag or Diestian of Belgium. He recognized that the St. Erth Beds were of similar age and not newer. Speaking of the Lenham Mollusca, he stated that *Arca diluvii* was new to England, and that *Pleurotoma consobrina* (?) and *P. jouanneti* (?) were species belonging to the Upper Miocene of the Continent. His list of determinations, endorsed by Messrs. Sharman and E. T. Newton, included 16 Gastropods, 21 Pelecypods, and 1 Brachiopod.

Four years later fuller particulars of the Lenham deposits were published by the same author [7] in a memoir on the British Pliocenes. They were alluded to as occurring in pipes of the Chalk formation,

[1] "Note on supposed Remains of the Crag on the North Downs near Folkestone": Quart. Journ. Geol. Soc., vol. xxii, p. 553, 1866.

[2] "On the Belgian Tertiaries": Geol. Mag., 1867, p. 502.

[3] "Contributions to a Knowledge of the Newer Tertiaries of Suffolk and their Fauna": Quart. Journ. Geol. Soc., vol. xxvi, pl. xxxiv, figs. 5–10, p. 499, 1870.

[4] *Géologie de la Belgique*, vol. i, p. 268, 1880.

[5] "Contribution à l'Etude des Terrains Tertiaires de la Belgique": Bull. Soc. R. Mal. Belgique, vol. xvii, pp. xliii–xlv, 1882.

[6] "The Pliocene Deposits of North-Western Europe": *Nature*, vol. xxxiv, pp. 341–3, 1886.

[7] *The Pliocene Deposits of Britain—Lenham Beds* (*Diestian*) (Mem. Geol. Surv.), 1890, pp. 2, 42–58, etc.

frequently at considerable heights above the sea, near Lenham itself being found at 680 feet above sea-level. The whole of the British Pliocene series were grouped into "Newer" and "Older", the latter containing the following divisions:—

Older Pliocene.	
St. Erth Beds.	Lenham Beds.
Coralline Crag.	Box-stones.

In connection with the Lenham Mollusca it was stated that such southern genera as *Ficula* (*Pyrula*), *Xenophora* (*Phorus*), *Triton*, and *Avicula*, occurring in association with a profusion of *Arca diluvii*, *Cardium papillosum*, and some South European extinct species of *Pleurotoma* and *Terebra*, represented a fauna in favour of a southern or Mediterranean origin.

A full list of fossils from the Lenham and other Pliocene deposits of England was given in tabular order, showing the distribution of each species in Belgium, France, etc., the Lenham shells alone including 65 species, made up of 27 Gastropoda, 1 Scaphopoda, 36 Pelecypoda, and 1 Brachiopoda, as follows:—

Gastropoda.
- *Actæon tornatilis*, Linnæus.
- *Aporrhais pespelicani*, Linnæus.
- *Buccinum dalei*, J. Sowerby.
- *Cancellaria contorta*, Basterot.
- *Cerithium tricinctum*, Brocchi.
- *Cypræa europæa*, Montagu.
- *Emarginula fissura*, Linnæus.
- *Eulima subulata*, Donovan (?).
- *Fissurella græca*, Linnæus.
- *Margarita trochoidea*, S. V. Wood.
- *Nassa prismatica*, Brocchi.
- *Natica millepunctata*, Lamarck.
- *N. varians*, Dujardin.
- *Pleurotoma consobrina*, Bellardi.
- *P. jouanneti*, Desmoulins.
- *P. turrifera*, Nyst.
- *Pyrula reticulata*, Lamarck.
- *Ringicula ventricosa*, J. Sowerby.
- *Scalaria clathratula*, Adams.
- *Scaphander lignarius*, Linnæus.
- *Terebra acuminata*, Borson.
- *Triton heptagonum* (?), Brocchi.
- *Trochus cinerarius*, Linnæus.
- *T. millegranus*, Philippi.
- *T. ziziphinus*, Linnæus.
- *Turritella planispira*, S. V. Wood.
- *Xenophorus* sp.

Scaphopoda.
- *Dentalium dentalis* (?), Linnæus.

Brachiopoda.
- *Terebratula grandis*, Blumenbach.

Pelecypoda.
- *Arca diluvii*, Lamarck.
- *A. lactea*, Linnæus.
- *Artemis exoleta*, Linnæus.
- *Astarte basteroti*, Lajonkaire.
- *A. omalii*, Lajonkaire.
- *A. galeottii*, Nyst.
- *Avicula phalænoides* (?), S. V. Wood.
- *Cardita senilis*, Lamarck.
- *Cardium papillosum*, Poli.
- *Cardium*, n.sp.
- *Cyprina islandica*, Linnæus.
- *Cytherea chione*, Linnæus.
- *Diplodonta astartea* (?), Nyst.
- *D. dilatata*, S. V. Wood.
- *Donax politus*, Poli.
- *Gastrana fragilis*, Linnæus.
- *Hinnites cortesyi*, Defrance.
- *Isocardia cor*, Linnæus.
- *Leda semistriata* (?), S. V. Wood.
- *Lepton deltoideum*, S. V. Wood.
- *Lima loscombii* (?), G. B. Sowerby.
- *Lutraria elliptica*, Lamarck.
- *Mactra arcuata*, J. Sowerby.
- *Nucula sulcata*, Bronn.
- *Ostrea princeps*, S. V. Wood.
- *Pecten maximus*, Linnæus.
- *P. princeps*, J. Sowerby.
- *P. varius*, Linnæus.
- *Pecten*, n.sp.
- *Pectunculus glycimeris*, Linnæus.
- *Pholadidea papyracea*, Solander.
- *Solen ensis*, Linnæus.
- *Tellina benedeni*, Nyst.
- *T. donacina*, Linnæus.
- *Thracia pubescens*, Pulteney.
- *T. ventricosa*, Philippi.

The next paper of importance was by Mr. F. W. Harmer,[1] in which the Lenham Beds were regarded as of older age than the Coralline Crag, on account of the more southern facies of the fauna, some of the molluscan species being characteristic of Miocene or Italian Lower Pliocene, which are unknown or rare in the Coralline Crag. The author included a distribution table of shells from the Belgian Diestian beds, showing the Lenham occurrence as well as those found in the "Box-stones" of Suffolk. In the following year the same author[2] referred the Lenham Beds to the Older Pliocene under the new horizonal term of "Lenhamian", and further recognized them in a classification table as belonging to the "zone of *Arca diluvii*", and of the age of the Diestian sands.

A more extended scheme of the Pliocene deposits of the East of England was again published by Mr. Harmer,[3] based on his classification table of 1899. In this the Older Pliocene beds were divided into:—

LEN-HAMIAN.	LENHAM BEDS:	Zone of *Arca diluvii.*	Diestian.
	BOX-STONES	Base of Red Crag. / Base of Coralline Crag at Sutton.	Waenrode Beds (?).

The Coralline Crag deposits were scheduled as the basement of the Newer Pliocene series of rocks, which he had formerly placed in the Older Pliocene.

Mr. W. P. D. Stebbing[4] next announced the discovery of some molluscan remains in a patch of sand and ironstone at Netley Heath, Surrey, between Dorking and Guildford, along the top of the North Downs, at heights varying from 570 to 600 feet O.D. The specimens, consisting of sandstone casts, were referred to the genera *Cyprina* (?), *Modiola*, *Nassa*, *Trochus*, *Cardium*, *Pectunculus*, *Tellina*, and *Thracia*, no specific determinations being given. The author inclined to the view that these sandy deposits were a westerly extension of the Lenham Beds near Maidstone, and those at Paddlesworth north of Folkestone.

Referring to the Lenham fossils, which Mr. E. Van den Broeck[5] had examined at the Museum of Practical Geology, that author was of opinion that they represented a fauna of Diestian age. He noted the presence of older forms corresponding to the Bolderian (Upper Miocene) fauna of Belgium, and among the Box-stones at the Ipswich Museum he identified species found in the Belgium Miocene. He concluded, therefore, that the Lenham Beds were Diestian, and that the Box-stones corresponded with the Bolderian of Belgium, or

[1] "The Pliocene Deposits of the East of England; the Lenham Beds and the Coralline Crag": Quart. Journ. Geol. Soc., vol. liv, p. 308, 1898.

[2] "On a proposed new Classification of the Pliocene Deposits of the East of England": Rep. Brit. Assoc. (Dover), 1899, p. 752.

[3] "The Pliocene Deposits of the East of England, part ii: The Crag of Essex (Waltonian) and its Relation to that of Suffolk and Norfolk": Quart. Journ. Geol. Soc., vol. lvi, p. 708, 1900.

[4] "Excursion to Netley Heath and Newlands Corner": Proc. Geol. Assoc., vol. xvi, pp. 524–6, 1900.

[5] "Le Diestien et les Sables de Lenham, le Miocene démantelé et les Box-Stones en Angleterre": Bull. Soc. Belg. Géol. (Bruxelles) Procès-verbaux, vol. xvi, pp. 170–3, 1902.

DISTRIBUTION TABLE OF THE LENHAM MOLLUSCA AND BRACHIOPODA.

GENERA AND SPECIES.	GEOLOGICAL HORIZONS.																		
	Aquitanian. 1	Burdigalian. 2	Vindobonian. 3	Redonian. 4	Messinian. 5	Box-stones. 6	Lenham Beds. 7	St. Erth Beds. 8	Coralline Crag. 9	Bolderian. 10	Anversian. 11	Diestian. 12	Scaldisian. 13	Plaisancian. 14	Astian. 15	Red Crag. 16	Norwich Crag. 17	Post-Pliocene. 18	Recent. 19
GASTROPODA—																			
Capiluna græca, Linnæus, sp.			x	x			x		x				x			x			x
Emarginula fissura, Linnæus, sp.				x			x		x		x		x	x	x	x			x
Eumargarita trochoidea, S. V. Wood, sp.							x						x			x		x	x
Calliostoma zizyphinum, Linnæus, sp.						x	x	x	x			x	x			x			x
Ampullotrochus miliaris, Brocchi, sp.			x		x		x	x	x		x			x	x				x
Capulus ungaricus, Linnæus, sp.			x	x			x	x	x			x	x			x		x	x
Trivia europœa, Montagu, sp.			x	x			x	x	x		x	x	x	x	x	x		x	x
Ptychopotamides tricinctus, Brocchi, sp.			x	x			x	x					x	x	x	x	x	x	
Scala subulata, J. de C. Sowerby, sp.							x		x			x	x			x			(?)
Hyaloscala clathratula, Kanmacher, sp.				x			x		x			x	x						x
Pyramidella plicosa, Bronn, sp.			x		x		x		x		x			x	x	x			
Subularia subulata, Don., sp.			x		x		x	x	x		x	x	x	x	x				x
Zaria subangulata, Brocchi, sp.			x		x		x	x	x		x			x	x				
Xenophora crispa (?), König, sp.							x							x	x				
Aporrhais pespelecani, Linnæus, sp.			x				x		x		x	x	x	x	x	x	x	x	x
Semicassis saburon, Brug., sp.			x		x	x	x				x		x	x	x	x			x
Ficus reticulata, Lamarck			x	x	x	x	x		x	x	x	x		x	x	x			x
Streptochetus sexcostatus, Beyrich, sp.			x		x		x				x								
Tritia limata, Chemnitz, sp.		x	x	x	x		x		x		x		x	x	x				x
Murex badensis, Nyst			x				x		x				x			x			
Boreotrophon clathratum, Linn., sp.							x		x	x						x	x	x	x
Trophonopsis muricatus, Montagu, sp.				x			x						x			x		x	x
Bonellitia serrata, Bronn, sp.			x				x							x					
Maculopeplum lamberti, J. Sow., sp.			x	x		x	x		x			x	x			x			
Turris turrifera, Nyst, sp.			x		x		x			x	x	x	x	x	x	x		x	
Drillia obeliscus, Des Moul., sp.		x	x		x		x			x	x	x							
Clavatula jouanneti, Des Moul., sp.		x	x				x												
Terebra acuminata, Borson			x		x		x				x			x	x				
Actæon tornatilis, Linnæus, sp.			x		x		x		x		x	x	x	x	x	x	x		x
Ringiculella lenhamensis, sp.n.							x												
Scaphander lignarius, Linnæus, sp.			x	x	x		x		x	x	x	x	x	x	x	x			x
Bullinella cylindracea, Pennant, sp.			x	x	x		x		x		x	x	x	x	x	x			x
SCAPHOPODA—																			
Dentalium entale, Linnæus			x		x	x	x				x	x	x	x			x	x	x
PELECYPODA—																			
Nucula proxima, Say							x	x	x		x							x	x
Nucula cf. *sulcata*, Bronn			x				x	x						x	x				x
Yoldia oblongoides, S. V. Wood, sp.							x									x	x	x	

DISTRIBUTION TABLE—(*continued*).

GENERA AND SPECIES.	GEOLOGICAL HORIZONS.																		
	Aquitanian. 1	Burdigalian. 2	Vindobonian. 3	Redonian. 4	Messinian. 5	Box-stones. 6	Lenham Beds. 7	St. Erth Beds. 8	Coralline Crag. 9	Bolderian. 10	Anversian. 11	Diestian. 12	Scaldisian. 13	Plaisancian. 14	Astian. 15	Red Crag. 16	Norwich Crag. 17	Post-Pliocene. 18	Recent. 19
PELECYPODA (*continued*)—																			
Monia patelliformis, Linnæus, sp.							x		x					x	x	x	x	x	x
Anadara diluvii, Lamarck, sp.			x		x		x			x	x			x					
Fossularca lactea, Linnæus, sp.			x	x			x		x					x	x	x		x	x
Glycymeris pilosa, Linnæus, sp.			x	x	x	x	x	x	x		x	x	x		x				x
Mytilus edulis, Linnæus, var. *ungulatus*, Poli							x									x			x
Volsella barbata, Linnæus, sp.							x							x		x			x
Margaritifera phalænacea, Lamarck, sp.	x	x	x				x		x		x			x					
Ostrea princeps, S. V. Wood							x		x			x	x			x			
Pecten maximus (?), Linnæus, sp.							x	x	x		x	(?)	x			x			x
Æquipecten opercularis, Linnæus, sp.					x	x	x	x	x			x	x	x	x	x	x	x	x
Manupecten pesfelis, Linnæus, sp.			x	x			x							x	x				x
Chlamys princeps, J. de C. Sow., sp.							x		x				x				x		
Hinnites crispus, Brocchi, sp.					x	x	x		x					x	x	x			
Glans senilis, Lamarck, sp.			x	x			x		x				x			x			
Astarte basteroti, Lajonkaire				x			x		x			x	x			x			
A. galeottii, Nyst							x		x				x			x			
A. omalii, Lajonkaire			x	x			x		x	x	x	x	x			x		x	
A. mutabilis, S. V. Wood							x		x		x		x			x			
Cyprina rustica (?), J. Sowerby, sp.			x		x	x	x		x		x	x	x			x			
Isocardia humana (=*cor*), Linn., sp.			x				x		x			x				x			x
Dentilucina borealis, Linnæus, sp.			x	x	x		x	x	x		x	x	x	x	x	x	x	x	x
Arcopagia ventricosa, Serres, sp.			x				x							x	x				
Tellina benedeni, Nyst & West			x		x		x			x	x	x	x			x			
Moera donacina, Linnæus, sp.			x				x		x				x	x	x	x		x	x
Gastrana laminosa, J. de C. Sow., sp.							x		x				x			x			
Spisula arcuata, J. Sowerby, sp.							x			x		x	x			x	x	x	
S. subtruncata, Da Costa, sp.			x	x		x	x	x	x				x	x	x	x	x	x	x
Pitar rudis, Poli, sp.			x	x			x		x				x	x	x	x		x	x
Callista chione, Linnæus, sp.			x	x			x		x	x	x	x	x	x	x	x			x
Tapes perovalis, S. V. Wood							x		x										
Papillicardium papillosum, Poli, sp.			x	x	x		x	x						x	x				x
Plagiocardium hirsutum, Bronn			x				x							x	x				
Ensis ensis, Linnæus, sp.			x	x			x	x	x		x	x	x	x	x	x		x	x
Cyrtodaria angusta, Nyst & West, sp.					x	x	x		x	x	x	x	x			x			
Panopæa menardi, Deshayes			x		x	x	x		x		x					x			
Barnea cylindrica, J. Sowerby, sp.							x									x			
Aspidopholas rugosa, Brocchi, sp.							x							x	x				
Pholadidea papyracea, Turton, sp.				x			x		x		x	x							x
Thracia convexa, W. Wood			x			x	x		x					x	x			x	x
T. pubescens, Pulteney, sp.			x				x		x				x	x	x			x	x
BRACHIOPODA—																			
Terebratula perforata, Desnoy				x			x		x	x	x	x	x			x			

probably a more recent horizon which represented the Mio-Pliocene or Older Pliocene, a period slightly anterior to the Diestian. He was also of opinion that the zones of *Terebratula grandis* and *Isocardia cor* could not be separated, but belonged alike to the Diestian division of the Pliocenes.

In a further contribution, Mr. Harmer[1] regarded the Lenham Beds as synchronous with the ferruginous sandstones of Louvain and Diest. He stated that among the Diestian sandstone fossils were about sixty species of Mollusca, some being Crag forms, whereas a few were of an older or Miocene type and not found in the Coralline Crag; similarly the Lenham shells included many Miocene species, such as *Terebra acuminata*, *Triton heptagonum*, *Pleurotoma consobrina*, *P. jouanneti*, *Cancellaria contorta*, *Hinnites cortesyi*, and *Arca diluvii*. A table of the British Pliocene deposits was included, being nearly similar to that issued by the same author in 1900, in which the "Lenhamian" formed the lowest of the Pliocene stages, the Box-stones being regarded as equivalent to the Waenrode Beds of Belgium (Bolderian, according to Mr. Van den Broeck).

Subsequently Mr. Harmer[2] repeated his former views on the age of the Lenham deposits, the fauna being spoken of as presenting a distinctly older type than that of the Coralline Crag and approaching more nearly a Miocene facies, instancing, among other shells, the abundance of *Anadara diluvii*, which occurs in the Vienna Basin, the Touraine area of France, and the Bolderian of Belgium.

In their memoir on the geology of Holland, Messrs. G. A. F. Molengraaff and A. J. M. Van Waterschoot Van der Gracht[3] referred to the occurrence of *Anadara diluvii* in the Lenham Beds as indicative of a Miocene age, the same shell being found in the Miocene deposits of Peel and Winterswyk in Holland, the rocks of the former place being stated as the equivalent of the "Glimmertons" of the north of Germany or the Tortonian stage of the Miocene, whilst the beds at Winterswyk were regarded as Middle Miocene. This work also included lists of molluscan species from the Upper and Middle Miocene deposits of Holland, many of which are found in the Lenham Beds.

Another reference to the geological aspect of this subject has been made by Mr. F. W. Harmer[4] in an "Introduction" to a new work on British Pliocene Mollusca, where he adheres to his previously expressed views that the Lenham Beds with the "Box-stones" and the Belgian Diestian deposits should be grouped as Lower Pliocene and that the Coralline Crag beds of East Anglia should form the base of the Upper Pliocenes.

A final notice to make involves a slight alteration in the views of Mr. C. Reid,[5] who, in a work recently published, places the Coralline

[1] "A Sketch of the Later Tertiary History of East Anglia": Proc. Geol. Assoc., vol. xvii, pp. 416–79, 1902.

[2] "The Pliocene Deposits of the Eastern Counties of England": Geol. Assoc., Jubilee Volume, 1908, pp. 86–102.

[3] "Niederlande": Handb. Region. Geol., vol. i, pt. iii, pp. 51–3, 1913.

[4] *The Pliocene Mollusca of Great Britain* (Mon. Pal. Soc.), 1914, pt. i, p. 5.

[5] C. & E. M. Reid, "The Pliocene Floras of the Dutch-Prussian Border": Mededeel. Rijks. Delfst., 1915, No. 6, p. 9.

Crag and Lenham Beds in the Lower Pliocene group, bracketing them as equivalent to the Diestian—but the "Box-stones" are scheduled as Miocene.

(*In July will follow Mr. Newton's conclusions.*)

II.—The Horizon of the Type-specimens of Dr. Scouler's *Dithyrocaris tricornis* and *D. testudinea*. By Peter Macnair, F.R.S.E., F.G.S.[1]

Introduction.

THE exact locality and as a consequence the precise geological horizon from which the type-specimens of *Dithyrocaris tricornis* and *D. testudinea* were obtained has long been a matter of considerable uncertainty. These type-specimens, now preserved in Kelvingrove Museum, were first described by Dr. John Scouler in the *Records of General Science* for the year 1835 (p. 137). The object of this paper is to demonstrate that these fossils came from what was known as the Gallowhill Quarries, and that they occupy a position near the top of the Blackbyre Limestone of this district.

Regarding the beds in which they were found Dr. Scouler says: "This limestone is situated about a mile to the east of Paisley, and was first pointed out to me by Mr. Murray, of the Glasgow Botanic Gardens. This rock is distinct from and probably reposes on the true Carboniferous Limestone, but as only a small patch of it is exposed, the greater part being covered by the soil, it was impossible to trace its relations with the subjacent strata. This limestone is of an extremely compact nature, with little plates of calcareous spar disseminated through its substance. It readily splits into flags of variable thickness, which are sometimes made of a multitude of extremely thin layers, indicating that the whole stratum has been formed by the gradual and tranquil deposition of transported matters. The organic matters differ widely from those which we observe in the Carboniferous Limestone. I could detect no *Productidæ* nor any fragments of corals or stems of crinoid animals, nor, in short, any decidedly massive production. Instead of these, on splitting up the rock we observe impression of ferns of great variety and beauty, the remains of entomostraca, which are of gigantic size when compared with the analogous species which still abound in our lakes and pools. Two species belonging to a new genus were obtained, and the numbers might have been greatly increased had not the hardness of the rock rendered the extraction of the specimens a difficult task." It will be noted that though in the above account no definite locality is mentioned, yet they are recorded as coming from a locality about a mile to the east of Paisley. Another important feature of this account is that it is such an exact description of the nature of the limestone in which the fossils occur that we can have no hesitation in identifying it with the bed to be described subsequently in this paper.

[1] Reprinted in a slightly abridged form from the Transactions of the Geological Society of Glasgow, vol. xvi, pt. i, 1915–17.

In the *New Statistical Account of Scotland*, published in 1845, under the section "Town and Parishes of Paisley", we find the following important reference to this limestone and these fossils (1845, p. 157). It is of very great interest, because it appears to have hitherto escaped notice, and because it cites the Farm of Gallowhill as the exact locality where the fossils were obtained. The reference runs as follows: "To the north-east of Paisley, on the Farm of Gallowhill, a quarry has of late been wrought in an extensive bed of schistose rock lying almost horizontally about 3 feet below the surface. Its colour is dark grey approaching to black. Its texture is compact and fine grained, and it readily splits into layers, but is with difficulty broken across. The fracture is splintery and rather conchoidal. It is composed of about 32 per cent. of carbonate of lime, 47 of sand, and 9 of alumina. This rock abounds in beautiful specimens of many genera and species of ferns, as also of shells, chiefly Terebratula, Nucula, and Orthoceratites. The layer of till immediately above this rock for several inches closely resembles Fuller's earth." The most interesting point, however, bearing upon the locality from which Scouler obtained his fossils is contained in the following footnote, which is added: "Two species found here belonging to a rare genus are described by Dr. Scouler in Thomson's Records of General Science, vol. i."

In 1865 Mr. James Armstrong (1865, p. 74) states in a paper published in the *Transactions* of this Society that specimens of *Dithyrocaris* were obtained by Dr. Scouler upwards of thirty years ago in a limestone excavated for the foundations of the Paisley Barracks.

In a paper read to the Society in 1893 Mr. James Neilson (1893, p. 71) makes the following statement regarding the locality where the type-specimens of *Dithyrocaris tricornis* and *D. testudinea* were found: "It is worthy of notice that when the late Dr. Scouler first discovered *Dithyrocaris* at Inkerman, near Paisley, nearly the entire animal was got. These beds were afterwards lost, and during many years since, the finding of only one or two carapaces has been recorded." From this it will be seen that Mr. Neilson, in utter disregard of any of the foregoing statements as to the locality at which the specimens were got, has shifted it to Inkerman, 1½ miles west of Paisley. But he gives us no reason for his doing so, and I am utterly unable to understand upon what grounds it was made.

In their memoir on the British Palæozoic Phyllocaridæ Professor T. Rupert Jones and Dr. Henry Woodward (1898, p. 147) still further complicate the matter, for in the text they say that Dr. Scouler's original specimen of *Dithyrocaris testudinea* is in hard, black, earthy limestone from the Carboniferous Limestone Series about a mile to the east of Paisley, the latter part of the sentence being quoted from Dr. Scouler's paper. But in a footnote they say, "At a place now called Inkerman, where Mr. R. Dunlop has lately most obligingly sought for further indications of these fossils, but without success." In this footnote they have evidently been misled by Mr. Neilson.

As we have already said, we hope to show that the statement made by the authors of the *Statistical Account* is probably the correct one, and that the specimens were got in a peculiar limestone which was formerly quarried on Gallowhill Farm, 1½ miles to the north-east of Paisley, and that both Mr. Armstrong's and Mr. Neilson's statements as to the locality where they were found are erroneous.

THE TYPE-SPECIMENS OF *DITHYROCARIS TRICORNIS* AND *D. TESTUDINEA*.

The type-specimens of the two species of *Dithyrocaris* were originally presented to the Anderson College Museum by Dr. Scouler, and some years ago were gifted, along with other specimens, to Kelvingrove Museum by the Governors of the Royal Technical College. *D. tricornis* shows the two valves of the carapace lying in an almost symmetrical position, but reversed so that the anterior part is approximately in the position that the posterior part ought to be, a phenomenon not unusual in decaying and floating Phyllopods.

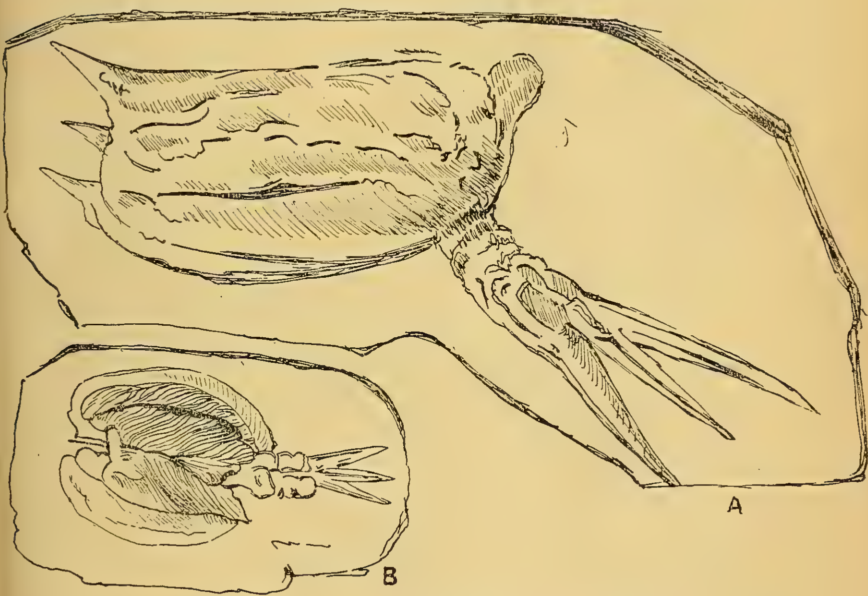


FIG. 1.—A. *Dithyrocaris tricornis*, Scouler. B. *D. testudinea*, Scouler. From the original drawings in Scouler's paper. The type-specimens are now in Kelvingrove Museum.

The three somewhat obscure abdominal segments and a tail with three spines project from the lower part of the front of the carapace. The gastric teeth are exposed through the test.

In *Dithyrocaris testudinea* the broad oval carapace is semi-elliptical in shape. The two valves lie in opposition by their dorsal edges, and overlap irregularly towards the lower half of the dorsal region. In both valves the central border is seen to terminate in a small obscure spine. A strong ridge showing the characteristic rugose structure of the overlapping chevron-shaped scales runs down the middle of each valve. The abdominal segments which project from behind the carapace have been considerably crushed. The three caudal spines are well shown. They are of nearly equal length, stout, fluted, and show traces of granulation on the riblets. Fig. 1, which shows *Dithyrocaris tricornis* and *D. testudinea*, is after the original drawing in Dr. Scouler's paper.

The only other fossil preserved on the slabs containing the type-specimens is a single specimen of *Lingula mytiloides*, which is seen on the large slab with *Dithyrocaris tricornis*. As we shall presently see, this is the commonest of all the fossils found in the Gallowhill Limestone, in which it is often exceedingly numerous.

THE GALLOWHILL LIMESTONE.[1]

About two years ago my attention was first directed to the peculiar character of the limestone that forms the wall to the east of Gallowhill, near Paisley. The locality from which Scouler's type fossils had been obtained had for a long time exercised my mind, as it had done that of other local geologists, and when I first saw the limestone of which the wall is built I was at once struck with its strong similarity to that forming the matrix of the Scouler fossils. I took a specimen of the limestone with me, and a comparison of it with the specimens in the museum at once confirmed their identity. Both present the same earthy-like appearance, their joint faces being lined with calcite, and strongly charged with iron pyrites in nodular masses and in strings and isolated cubes. Associated with the limestone are bands of a much more argillaceous and sandy nature, of which examples may be seen in the dykes and bings, the large bing to the south of Gallowhill House having yielded numerous examples of the different types of sedimentation that appear to have prevailed upon this horizon. I am indebted to Mr. R. S. Houston for the following analysis of the limestone, which, like the analysis given in the *Statistical Account*, shows that it contains a large percentage of siliceous and clayey matter:—

Carbonate of lime	48·67
Carbonate of magnesia	·98
Carbonate of iron	5·70
Alumina	1·02
Siliceous matter (clay)	40·23
Carbonaceous matter	2·30
Moisture	·57
	99·47

After convincing myself of the lithological identity of the two limestones I began to search for some evidence of a Phyllopod fauna, and was soon rewarded by clear evidence of its presence. Nothing to equal Scouler's specimens has yet been found, but fragments of carapaces and tail spines are sufficiently numerous and in a similar state of preservation to conclusively demonstrate the identity of the

[1] It should be clearly understood that the local term "Gallowhill Limestone" used throughout this paper does not stand for any new limestone horizon, but is only used to express a peculiar phase occurring at the top of the Blackbyre Limestone. This, indeed, is the main object of the paper.

Gallowhill Limestone with that which forms the matrix in which Scouler's fossils are preserved. The most abundant fossil in the Gallowhill Limestone is *Lingula mytiloides*, many of the slabs being simply crowded with them. The full significance of the faunal association found in the Gallowhill Limestone will, however, be discussed in more detail presently. In his paper Scouler refers to the absence of Productidæ, corals or stems of crinoid animals, but *Productus longispinus* and *Rhynchonella pleurodon* are fairly abundant on some slabs. Slabs of the limestone rich in crinoidal remains have also been observed. But whether these represent the same bed as that which carries the Phyllopod fauna or one on a slightly different horizon we have not yet been able to determine definitely, but we are inclined to favour the latter view.

Arkleston Cutting and Former Exposures at Gallowhill.

In my paper on the Hurlet sequence in North Ayrshire I have given an account of the strata exposed in the Arkleston Cutting, and it is there shown that the top limestone is the Hurlet Limestone, here 3 to 4 feet thick and dipping towards the east. Below it comes the Hurlet Alum Shale, only some 6 inches thick, followed by the Hurlet Coal, originally from 5 to 6 feet thick. The coal has been split up the centre by a sill of dolerite, some 80 feet in thickness, lenticles of the coal occurring within the sill. Below the sill comes some 18 feet of shale and fireclay, in which there is a limestone in three seams full of entomostraca and fish remains, and which is clearly the equivalent of the Baldernock Limestone of the Campsie district. The whole group of sedimentary strata is much pyritized and altered by contact with the intrusive sill of dolerite. A search for the alum shale fauna in the fragments that are seen to lie above the sill has not as yet been successful in yielding any examples of that characteristic fauna, as the shale is very completely baked. But the discovery of the fauna at this point is not yet regarded as entirely hopeless. I have also shown in the paper mentioned that a highly fossiliferous limestone was at one time exposed between the bridge and the signal box, and that, dipping towards the east, it passed beneath the strata in the cutting just described. A consideration of all the available palæontological and stratigraphical evidence goes to show that this limestone must have been the equivalent of the Blackbyre Limestone.

If we turn to the 6-inch-to-the-mile Geological Survey map, of which Fig. 2 is in part a reproduction, it will be noticed that the limestone, there shown as trending northwards towards the Arkleston Print Works, and then bifurcating into two outcrops towards the north-west, clearly lies below the sill now seen in the cutting. When the Geological Survey map was made in the year 1875 the railway ran through a tunnel at this point, and the Hurlet Limestone lying above the sill does not appear to have been exposed. If it was it is not indicated on the map. The limestone represented on the map is drawn as two narrow outcrops at the Paisley end of the tunnel. Unfortunately no exposure can now be observed between the bridge over the railway and the signal box. But that a limestone was at

FIG. 2.—Sketch-map and section along the railway at Arkleston, Paisley. *a*, Blackbyre Limestone with Gallowhill Limestone phase at top; *b*, Cementstone with rootlets; *c*, Entomostracan Limestone; *d*, shales and fireclay; *e*, dolerite sill; *f*, Hurlet coal; *g*, alum shale; *h*, Hurlet Limestone.

one time exposed at this point is made clear both by the Survey map and by Mr. Blair's paper published in our Transactions (1889, p. 133). In this paper Mr. Blair describes it as exhibiting "a wider variety and more abundant quantity of delicate organisms than I have yet seen in any of these deposits".

The section between the railway bridge and the signal box at the Paisley end of the cutting is now so completely grassed over that not a vestige of rock can now be seen, and we are left to judge by analogy with the general sequence of the district what the horizon of the limestone formerly exposed at this point may be. Fortunately, though exposures are extremely rare upon this horizon in this district, yet the cumulative evidence is such as to leave no room for any doubt in our minds that the limestone formerly exposed at this point, known locally as the Gallowhill Limestone, must be the equivalent of the Blackbyre Limestone of the Hurlet type section. On the east side of the railway bridge the lowest bed seen in the railway cutting is a band of grey cement limestone with rootlets, which all over this area is a well-marked horizon lying immediately below the Hurlet Coal and above the Blackbyre Limestone. It can be seen at Crookston Farm cropping from below the dolerite sill in exactly the same fashion as it does in this cutting, but there in addition to the rootlets it contains fish teeth, *Spirorbis*, and entomostraca.

Below this rooty cementstone there comes in the Hurlet district a variable thickness of shales succeeded by the Blackbyre Limestone. This view has been expressed in the section in Fig. 2; *a* is the Gallowhill Limestone, being the top of the Blackbyre Limestone, shown as folded into a gentle arch, which gives off in its eastern limb, *b* the cement limestone with rootlets, *c* thin bands of limestone with entomostraca and fish remains, *d* beds of shale and fireclay, *e* intrusive sill of dolerite, *f* and *g* Hurlet Coal and alum shale, and *h* Hurlet Limestone.

As has already been stated, no exposures of the Gallowhill Limestone can now be seen at any of the localities where it was formerly worked. But the position of two of the quarries south of the Arkleston Print Works can still be seen. Another quarry appears to have been opened a little to the south of Gallowhill, opposite the Mote Hill. The positions of these quarries are indicated on the map, and they seem to have been somewhat extensively worked about the year 1835, when Scouler's fossils were found, the old Powder Magazine between Arkleston and South Arkleston having been built of it, as well as a large number of the dykes in the Gallowhill Policies. It was also used in some walls in the neighbourhood of the Paisley Barracks, where it can still be seen. This may have something to do with Armstrong's statement that Scouler's fossils were found in a limestone excavated for the foundations of the Paisley Barracks.[1] That the Gallowhill Limestone must extend considerably

[1] Since writing this paper I have been informed by Mr. R. Houston that in making the foundations for the villas adjoining the Paisley Barracks it was found that slabs of the Gallowhill Limestone had been used to fill up old hollows in the surface of the ground.

to the west of the outcrop, as drawn on the map, is made clear both from the evidence derived from the old quarry opposite the Mote Hill and also from recent information that we have obtained which shows that Gallowhill House rests upon it. But whether it is continuous over this area or is repeated by faulting we have no data to decide, and the position of the outcrop is left much as it is given in the 6-inch-to-the-mile Geological Survey map.

The statement in the *Statistical Account* that the layer of till immediately above the Gallowhill Limestone for several inches closely resembles fuller's earth is of great interest, as we seem to recognize in this the peculiar ashy fireclay which is generally found to rest on the eroded top of the Blackbyre Limestone of Renfrewshire and North Ayrshire.

In interpreting the structure of the ground between Arkleston and the Cart it seems to us that there must be a low arch bringing in the strata that lie immediately below the Hurlet Limestone. On the east this arch sinks below the Hurlet Limestone, as exposed in the Arkleston Cutting, and on the west it must pass below the outcrop of the Hurlet Limestone and Coal which has been drawn by the Survey to cross the White Cart Water near Carlisle Quay and Nethercommon. An exposure of limestone underlaid by a bed of coal with pyrites can at present be seen at low tide immediately below the Swing Bridge at Carlisle Quay, but owing to the limited nature of the exposure it is at present difficult to determine whether this is the Hurlet Limestone or the Blackbyre Limestone, but it is certainly the equivalent of one of these.

Bores put down along the outcrop of the dolerite on the Gallowhill Policies show that the dolerite rests along this line upon a series of thick-bedded shales, fireclays, and sandstones which have been bored into for a depth of more than 30 fathoms. There can scarcely be any doubt that the uppermost of these represent the sediments which lie between the Blackbyre Limestone above and the Hollybush Limestone below. On the 6-inch-to-the-mile Geological Survey map a bore put down to the south of Gallowhill shows the presence of a coarse limestone 1 ft. 7 in. thick at a depth of 12 fathoms. This is probably upon the position of the Hollybush Limestone.

Comparison with the Blackbyre Limestone at other Localities.

From the evidence that has been adduced there can be no doubt that the Gallowhill Limestone must lie somewhere on the horizon of the Blackbyre Limestone, and we now pass to consider the evidence that exists bearing upon the lithological and palæontological characteristics of the Blackbyre Limestone in this district. At the type locality (Blackbyre Farm) the Blackbyre Limestone consists of two parts, a lower full of small Brachiopods, largely *Productus longispinus*, and an upper part which is crinoidal. Neither of these, however, can be compared with the Gallowhill Limestone. As a rule, the Blackbyre Limestone of this district may be described as essentially a Brachiopod or shelly limestone with occasional bands of *Lithostrotion*. The contention of this paper is that the Gallowhill

Limestone is simply a phase characteristic of the top of the Blackbyre Limestone, and as the top of the limestone is not seen at the type locality it is quite possible that it may be present though not exposed.

The section exposed at Jenny's Well, a quarter of a mile to the east of Blackhall, Paisley, is practically a counterpart of that seen in the Arkleston Cutting, and the additional corroborative evidence bearing upon the relationship of the Gallowhill Limestone to the Blackbyre Limestone is so complete that it requires to be examined in some detail. The section shows a fairly continuous sequence from the Blackhall Limestone down to the base of the sill of dolerite which here occupies exactly the same stratigraphical position as in the Arkleston Cutting, having the Hurlet Limestone above and the Blackbyre Limestone below.

Unfortunately the outcrop of the Blackbyre Limestone cannot be seen, but its position is shown by a hollow immediately to the west of the dolerite sill, which runs in a north and south direction from the Cart up the side of Dykebar Hill, marking the line along which it was formerly quarried. Just at the point where the road crosses the railway the Blackbyre Limestone was exposed during the making of the line. It cannot now be seen, but the walls on each side of the railway at this point are built of it, and the blocks of limestone show all the features of the Gallowhill Limestone on the one hand and of the Blackbyre Limestone of the type section on the other.[1]

An examination of the exposure of the Blackbyre Limestone seen in the bed of the Levern at Neilston, a little above the point where it crosses the main road to Lugton, helps, we think, to throw some light upon the relationship of the Gallowhill Limestone to the Blackbyre Limestone. The section here is somewhat obscure, but the main mass of the limestone is rich in corals and Productidæ. The former are represented by bands of *Lithostrotion* and solitary corals, the latter by various species of *Productus* and by numerous specimens of the large variety of *Productus giganteus*. On the top of the main mass of the limestone rests a bed of fine-grained cementstone, which presents all the features of the Gallowhill Limestone. Traced into North Ayrshire, it forms the peculiar fine-grained top of the Dockra Limestone and its equivalents, which we have elsewhere shown to be the same as the Blackbyre Limestone of the Hurlet section.

An examination of the sections exposed in the burn at Meikle Corseford, and on the Gryffe Water below Bridge of Weir, also affords certain evidence which goes to confirm the relationship of the Gallowhill Limestone to the Blackbyre Limestone. At both localities the Blackbyre Limestone is capped by a fine-grained crinoidal limestone comparable to the crinoidal phase of the Gallowhill Limestone. And at both these localities it is overlaid by the peculiar green ashy mud which is probably identical with the so-called fuller's earth found in the Gallowhill Quarry.

[1] The evidence derived from these blocks shows that the Blackbyre Limestone of this locality has a strong resemblance to that exposed in the Beith Quarries. It carries a varied Brachiopod fauna and contains thick bands of *Lithostrotion* and other corals.

THE FAUNAL ASSOCIATION OF THE GALLOWHILL LIMESTONE.

The fauna of the Gallowhill Limestone is an exceedingly characteristic one, and has a remarkable resemblance to that which exists on a much higher stratigraphical horizon, the Calderwood Cementstone of the East Kilbride district. So striking is the similarity between the two that we here institute a comparison between them to show that they must have been accumulated under closely similar physical conditions. Both in the Calderwood Cementstone and the Gallowhill Limestone the fossils are but sparingly distributed throughout the limestone, and the rarer forms only occur at wide intervals. The following list gives some of the principal species that occur in the Calderwood Cementstone at such localities as Burnbrae, Jackton Burn, Kirktonholm, Glebe Quarry, and Limekilns House.

Serpulites carbonarius, M'Coy.
S. membranaceus, M'Coy.
Spirorbis caperatus, M'Coy.
Dithyrocaris glabra, Woodw. & Eth.
D. granulata, Woodw. & Eth.
D. ovalis, Woodw. & Eth.
D. testudinea, Scouler.
D. tricornis, Scouler.
Palæmysis, Peach.
Palæcrangon, Salter.
Palæsquilla Pattoni, Peach.
Anthrapalæmon Coutsii, Peach.
Discina nitida, Phill.
Lingula squamiformis, Phill.
Productus semireticulatus, Mart.
P. longispinus, Sow.
Rhynchonella pleurodon, Phill.
Streptorhynchus crenistria, Phill.
Aviculopecten knockonniensis, M'Coy.
Posidonomya corrugata, Eth.
Nuculana attenuata, Flem.
Protoschizodus æquilateralis, M'Coy.
Nucula gibbosa, Flem.
Sanguinolites plicatus, Portl.
Orthoceras attenuatum, Flem.
Nautilus sp.

Serpulites carbonarius occurs in the Calderwood Cementstone, some slabs being simply covered with the tubes of this worm. In the Gallowhill Limestone they occur in exactly similar conditions. I have also found traces of *Serpulites membranaceus* and *Spirorbis caperatus* in the Gallowhill Limestone.

The Phyllopod Crustacea from the Gallowhill Limestone include, besides the two species *Dithyrocaris tricornis* and *D. testudinea*, others whose specific characteristics have not yet been determined. Their mode of occurrence and state of preservation are strongly suggestive of the conditions under which these fossils appear in the Calderwood Cementstone. No traces of the Schizopods which occur in the Calderwood Cementstone have as yet been found in the Gallowhill Limestone, but further search may yet reveal the presence of some of these most interesting forms.

The Brachiopod fauna of the Gallowhill Limestone is strikingly similar to that of the Calderwood Cementstone. In the Carluke district the Calderwood Cementstone is known as the Lingula Limestone, because of the large numbers of that fossil which occur in it. In the Gallowhill Limestone *Lingula squamiformis* is replaced by *Lingula mytiloides*, which, as has already been pointed out, occurs in great numbers. The more common Brachiopods in the Gallowhill Limestone are *Productus longispinus*, *P. semireticulatus*, and *Rhynchonella pleurodon*, and less commonly *Discina nitida* and *Streptorhynchus crenistria*.

Lamellibranchs are exceedingly scarce in the upper part or estuarine phase of the Gallowhill Limestone, but several specimens referable to *Sanguinolites plicatus* have been found, and one specimen closely resembling *Protoschizodus æquilateralis* and *Posidonomya corrugata* also occurs, and from the lower and more crinoidal parts *Nuculana attenuata* and *Nucula gibbosa* have been obtained.

The Cephalopoda are represented in the upper or estuarine part of the limestone by *Orthoceras attenuatum* and by a *Nautilus* which has not been specifically determined.

Fish remains, in the shape of scales, spines, and plates, occur in the upper part of the limestone, though in a somewhat fragmentary condition. They are clearly referable to those ganoids which are found in the estuarine facies of the Carboniferous formation.

Plant remains are fairly common, principally the fronds of ferns, and occurring as they do in association with the Phyllopods and with *Productus longispinus* and other Brachiopods they tend to accentuate the resemblance between the Gallowhill Limestone and the Calderwood Cementstone.

From what has been said it will be seen that the whole assemblage of plants and animals found in the Gallowhill Limestone is strikingly similar to that which occurs in the Calderwood Cementstone. That these strata are of estuarine origin is made clear by the manner in which the remains of land plants and animals are intermingled with those of estuarine and marine types, just as we find in estuarine deposits at the present day.

I have to acknowledge my indebtedness for much assistance in working out the details of the Gallowhill district to Mr. William Holmes, of Sandyford.

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REVIEWS.

I.—The Origin of the Earth. By T. C. Chamberlin. 8vo; pp. xi, 271. University of Chicago Press. 1916.

THIS book might appropriately have as a sub-title "The Intellectual Autobiography of a Geological Cosmographer and his Reflections on the Genesis and Geographical Evolution of the Earth". The author has collected into a small monograph the results of his studies of the origin of the earth, and the further development of his well-known planetesimal theory. The author tells us of the development of his interest in cosmography, and shows us the gradual growth of his present conclusions. He was first led into what he calls the "cosmographic fens and fogs" by his desire to reconcile the existence of former glacial periods with faith in an originally molten globe. He, therefore, with the aid of various mathematical friends, notably Professor Moulton, inquired whether the earth could have been in the condition of incandescent gas; and he was forced to abandon Laplace's nebular hypothesis. In the first series of chapters he points out the objections to it; he claims that it is inconsistent with the kinetic theory of gases, and that if the temperature were high enough to keep the very refractory constituents of the earth in a gaseous state they could not have been held together by gravity. He further holds that if the solar system had originated from a contracting nebula the equatorial velocity of the sun should be 270 miles per second, whereas it is only $1\frac{1}{3}$ miles per second. In reference to the support given to the nebular theory by the practical agreement of the average inclination of all the planets and planetoids to the plane of the solar equator with the requirement that they should revolve in that plane, he objects that the divergence of 5° is greater than should occur. A weightier objection is that though the sun is 744 times as great as all the planets together, yet they, $\frac{1}{745}$ of the mass, own 98 per cent of the momentum. The criticisms of Laplace's theory are undeniably very weighty. Professor Chamberlin admits its attractiveness, and remarks (pp. 61–2) that its long acceptance was the natural result "of its unsurpassed simplicity and beauty, and of the great service it has rendered the progress of thought", and of the "long list of general harmonies between the salient features of the solar system and the broader terms of the hypothesis. On such general harmonies the hypothesis was founded, and from these it gathered to itself a wide adherence".

The older forms of the meteoritic theory Professor Chamberlin also regards as unsatisfactory. He insists that Sir George Darwin's well-known demonstration that a swarm of small meteorites would behave physically as a gas in which each meteorite would act as a molecule rests on the doubtful assumption that the separate meteorites should have an elastic recoil like molecules. Professor Chamberlin's presentation of his own hypothesis is not free from serious difficulties, and is perhaps less attractive than in its original form. The planetesimals now play a comparatively small part. Professor Chamberlin regards the meteorites as fragments of an old world rather than as the germs of a new. He derives the solar systems from spiral nebulæ; and he attributes the latter to the scattering of the material of compact stars by that process of dynamic disruption the possibility of which was indicated by Roche. If two bodies approach one another their mutual attraction produces an internal tide that may break the surface and lead to the escape of a large mass of material through a solar prominence. The matter thus drawn upward may fall back to the parent body as a colossal deposit of volcanic agglomerate; or it may be raised so high as to remain suspended between the two bodies and revolve around the parent as a planet; or it may be captured by the attracting star and become its planet; or finally it may be shot off into space and escape from the influence of both bodies and give rise to a comet or swarm of meteorites. The tide may cause projections at opposite sides of the parent star, and the matter shot out may, it is held, remain connected to the parent by a nebular band, and thus give rise to a spiral nebula with the usual two arms. Professor Chamberlin suggests that the detached nebulous mass of the nebula M 51 in the constellation of the Hunting Dogs was due to a mass which was torn from the main nebula by the disruptive approach of another star and was left connected to it by a nebulous band.

According to Professor Chamberlin's theory, as the spiral nebulæ are due to the dynamic disruption of a compact and possibly cold star, they do not represent the original condition of matter. They are apparently an ephemeral stage in the life-history of solar systems. The genesis of such systems is therefore pre-nebular. If nebulæ are due either to direct collision or dynamic disruption their life should be comparatively short. The stars which blaze up in consequence of hypothetical collisions lose their sudden brilliancy in a few weeks or months; and if the light of the nebulæ is due to incandescence it ought soon to wane. The author has clearly shown the fundamental difficulties in Laplace's theory; but the nebulæ remain one of the most perplexing enigmas of the heavens. Indeed, several features in the solar system, such as the uniform direction of rotation of the vast majority of its members, in regard to the reasonable explanations that have been offered for the insignificant exceptions, agree better with the requirements of Laplace's theory than with that of the formation of nebulæ by Roche's dynamic disruption.

The second part of the book deals with the less speculative problems of geographical evolution, and it is interesting to note that the author, approaching the subject by his special route, lays much stress on the arrangement of the continents and the oceans as six interlocking triangles arranged around the Equator, on the antipodal position of land and water, and on the periodic variations of the major geographical processes in consequence of the deformation of the earth's crust. These views have been advocated in connexion with the tetrahedral hypothesis, to which the author does not refer. The conclusion in this part of the work to which many geologists are most likely to dissent is the adoption of the permanence of oceans and continents in an extreme form. The author attributes the position of the major elevations and depressions on the earth's crust to influences which acted upon it during its primary consolidation. Lord Kelvin adopted that conclusion and attributed the continents to segregations in the earth while it was still gaseous. Professor Chamberlin suggests they may be due to certain parts of the earth's surface having been cooled by descending currents of air in the anticyclones of the earth's primitive atmosphere.

The book deserves attention by all geologists interested in the early history of the earth, and can be read with interest by any student of either geology or geography. It gives comparatively few references; but those given are of special use to geologists by directing attention to astronomical and dynamical memoirs which they may easily overlook. The fewness of references is part of the method of the book. Its attractiveness is largely due to the personal element in it, which shows the mental processes by which the author felt his way from the problems of glacial climates to his illuminating contributions to the pre-geological history of the earth. J. W. G.

II.—The Dunstones of Plymouth and the Compton-Efford Grit. By R. H. Worth, M.Inst.C.E., F.G.S. Transactions of the Devonshire Association for the Advancement of Science, Literature, and Art, xlviii, pp. 217–59, 1916.

IN this paper the author sets forth some very revolutionary views regarding the Devonian igneous rocks of the Plymouth district. These rocks ("the Dunstones") are described by Mr. Ussher and Dr. Flett in the Geological Survey memoir of the Plymouth and Liskeard district as pillow lavas (spilites), diabases, and schalstein tuffs. The present author, however, comes to the conclusion that the rocks which he classes together under the old name of dunstones are all intrusive, there being no extrusive lava in the series which he has examined. The pillow structure which they exhibit is attributed to the rolling of parts of the walls of the fissure into the dunstone as it was intruded, since the pillows are generally attached to the main mass of the dyke and are surrounded by a skin of baked slate. The associated cherts, previously described as radiolarian cherts, are regarded as silicified slates, as they only extend over a space of the same extent as the dykes and are often included in the dyke or interbedded with thin layers of dunstone. There are three kinds of metamorphism associated with the intrusion of the dunstones, silicification, chloritization, and dolomitization, which with the baking, affect the surrounding slates, either together or separately in different places. The schalstein tuffs and breccias of the Survey memoir are described as being composite rocks of slate and dunstone, produced by the brecciation of the sides of the fissure, accompanied by the mixture of the slate fragments with the igneous rock. The dunstones are therefore regarded as having been intruded into the slates after they had developed a slaty cleavage. The Compton, Crabtree, and Wearde grits, which have been described as volcanic grits contemporaneous with the pillow lavas, are regarded as ordinary sediments, produced by the weathering of pre-existing igneous rocks, the evidence being drawn both from the mineral characters of the grits themselves and from the variety of the pebbles in the pebble bed associated with the grit and dunstone at Crabtree.

W. H. Wilcockson.

III.—A Synopsis of American early Tertiary Cheilostome Bryozoa. By Ferdinand Canu and Ray S. Bassler. United States Museum Bulletin 96. pp. 88, 6 pls. Smithsonian Institution. Washington, 1917.

AS one of the authors explains in his preface, the volume is a foretaste of a larger monograph on Tertiary Polyzoa; and, certainly, this hors d'œuvre whets the appetite for what is coming.

It consists of (1) a short statement of the principles of classification; (2) a systematic synopsis containing diagnoses both of the divisions of higher rank than generic, and of all new genera and species; and (3) figures of the new species.

To the general reader by far the most interesting section is the two pages devoted to the principles of classification; though the actual systematic scheme carries much that is of interest to the worker of Polyzoa, particularly to the specialist of Tertiary forms. And it is satisfactory to note, in this connection, that the fundamental divisions of the Cheilostomata adopted by Levinsen have been accepted here. The plates, too, call for congratulation, being, apparently, photographic reproductions of the originals, and, as such, are comparable with the excellent microphotographs of Cretaceous Polyzoa published by Brydone in the GEOLOGICAL MAGAZINE.

It is a pity that, with the need of establishing many new genera, more accuracy was not obtained in putting together the names. Here, especially indeed, the reviewer, having experienced the difficulties involved, would temper his criticism with sympathy. If the Latin ending -ella be permitted to Greek stems, the names *Otionella*, *Dacryonella*, *Aechmella* and others are both pleasant to hear and easy to pronounce; but not so *Stomachetosella*, which is also incorrectly formed, as are *Stamenocella* and *Trematoichos*. But *Metroperiella* is impossible, for περί is followed by nothing but a diminutive ending. *Metracolposa* and *Schizaropsis* would be more correct if, in the former, the first *a* were *o* and the final *a* dropped, and, in the latter, the second syllable omitted. *Velumella*, though sounding well, is an impossible form (*Velella* is, of course, preoccupied). What Lewis Carroll would have called the 'portmanteau' words *Membrendœcium* for "Membranipora with endozoœcial avicularia", *Cribrendœcium* for "Cribrilina with endozoœcial ovicells", *Schizemiella* —"'*schizos*,' slit" (there is no such word as 'schizos'), "'*emi*,' abbreviation for peristomie" (not very obvious!)—, and *Schizomavella* —"'mav,' abbreviation for median avicularium," whether pleasing or not, are ingenious. To take one more case—*Metradolium* should have *o* instead of *a*, and even then should mean "a thing that deceives its mother—(or ovicell)", and not "a deceptive ovicell", as intended.

It is impossible in a short notice to discuss adequately the principles of classification adopted. Possibly a better opportunity for this will arise when the larger monograph is published. Meanwhile we would offer our best wishes to the authors for their coming work, and our congratulations on its little forerunner.

W. D. L.

IV.—BRIEF NOTICES.

1. (1) BIBLIOGRAPHIE PRIMITIVE RELATIVE AUX BRYOZOAIRES. By F. CANU. Bull. Soc. Géol. France, ser. 4, vol. xv, pp. 287–292. 1916.

(2) BIBLIOGRAPHIE PALÉONTOLOGIQUE RELATIVE AUX BRYOZOAIRES DU BASSIN DE PARIS. By F. CANU. Bull. Soc. Géol. France, ser. 4, vol. xv, pp. 293–305. 1916.

(3) Les Bryozoaires fossiles des terrains du sud-est de la France. IX. Aquitanien. By F. Canu. Bull. Soc. Géol. France, ser. 4, vol. xv, pp. 320–334, pls. iii, iv. 1916.

(1) In the first of these papers, M. Canu gives a list of works dealing with Polyzoa from the years 1555–1792 inclusive, thus rendering available for students primitive works that otherwise may escape their notice.

(2) The second is a bibliography of the Eocene Polyzoa of the Paris basin, with lists of the species mentioned; for the sake of completeness, works dealing with Belgian and British Eocene forms also are included.

(3) In the third, M. Canu produces his ninth contribution to the Tertiary Polyzoa of S.W. France, namely those of Aquitanian age. Nine new species, illustrated in the plates by photographs of the originals, and one new genus are described.

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2. The Physical Conditions indicated by the Flora of the Calvert Formation. By E. W. Berry. U.S.A. Geological Survey, Prof. Paper 98–F, pp. 61–70, pls. xi–xii. 1916.

THE Calvert formation consists of diatomaceous earth, sandy clays, and marls, typically developed in Maryland. Owing to the quantities of diatoms present, there appears to have been assumptions in some quarters that a cold climate was indicated for the region at the time of their deposition. The most abundant plant remains are these diatoms, which have been much studied by experts, who have identified a large number of species indicating a habitat of relatively warm or sub-tropical temperature. The land plant species number twenty-six, of which twenty-three are Dicotyledons. Dr. Berry gives tables comparing these species both with the most similar fossil forms and the nearest living species, and concludes that they indicate "warm-temperate affinities comparable with the existing coastal floras of South Carolina and Georgia". The age of the flora is Middle Miocene or Tortonian.

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3. The Geological Factors affecting the Strategy of the War and the Geology of the Potash Salts. By Professor J. W. Gregory. Trans. Geol. Soc. Glas., xvi, pp. 1–33, 1916.

THE importance of coalfields in war strategy has been severely demonstrated by the occupation by Germany of the French, Belgian, and Polish fields, and to this topic Professor Gregory gives first place. He points out that "when the Peace Congress assembles, its meeting room might be appropriately provided with a geological map of Europe and Western Asia, since the resettlement of the frontiers will be largely dependent on geological influences, of which the diplomatists may have no conscious knowledge". The distribution of oilfields and of copper and iron ores is also discussed in relation to the War, but the most valuable part of the paper from the point of view of geologists is that which deals with the great German potash deposits. Their origin is dealt with and illustrated by many useful sketch-maps and sections, and much information published in a large paper by Everding in 1907 becomes available in English for the first time.

4. The Banket. By Robert B. Young. Gurney & Jackson, 1917. 8*s.* 6*d.* net.

As the formation, or rather the series of formations, responsible for the world's greatest goldfield, the banket of the Rand has naturally received much attention from geologists as well as from the miner, whose interest is purely economic. Professor Young's book is essentially a petrographic account of the banket and of the associated rocks, concluding with a discussion of the origin of the gold. Allogenic (including pebbles and matrix) and authigenic constituents are separately dealt with, gold being regarded as primarily a member of the former, though afterwards subject to solution and reprecipitation. A noteworthy feature of the book is the profusion and beauty of the plates with which it is illustrated.

5. Correlation and Chronology in Geology on the Basis of Palæogeography. By C. Schuchert. Bull. Geol. Soc. Am., vol. xxvii, p. 491, 1916.

In the first section of the paper the rise of geological chronology is described, and present views regarding the permanency of continents and oceans, and the bearing of diastrophism on chronology, are discussed. It is stated that crustal unrest is recorded in North America by at least fourteen epochs of mountain-making. Of these eight are "disturbances" of lesser import, while six are "revolutions" belonging to the more critical periods of the earth's history. The methods in use for the determination of stratigraphical sequence and correlation form the subject of the second section, and those dealt with are the sedimentary, the palæontological, the palæogeographical, and the diastrophic methods. The third section is devoted to the palæogeography of western North America during the Mesozoic Era, and nine maps illustrating the general conclusions are given.

6. On Synantetic Minerals and Related Phenomena. By J. J. Sederholm. Bull. Comm. Géol. Finlande, No. 48, 1916.

By the term *synantetic*, Sederholm proposes to designate those minerals that occur only where two definite minerals would otherwise meet. Such are the reaction rims, kelyphitic borders, and coronas occurring between various femic and salic minerals in basic rocks, and the intergrowth of plagioclase and vermicular quartz (to which the author gave the name *myrmekite* some years ago) that occurs in acid rocks between the boundaries of potash and soda-lime felspars. With regard to the former, which are described in great detail and with very full abstracts of the literature, Sederholm comes to the conclusion that they are referable to metamorphic processes. In the case of myrmekite and other analogous structures, the literature is again quoted at great length and a large number of new observations are placed on record. The various theories are critically discussed as to whether the structure is primary or secondary, due to volatile fluxes and solutions, to recrystallization in the solid state or to corrosion, whether it is more recent or older than the dynamo-metamorphism of the rocks in which it is displayed, and finally whether it is produced during the waning phase of plutonic activity, or during the beginning of a new phase which brings about the metamorphism of the rocks generated by the earlier phase. The author points out that no theory is wholly satisfactory, but he decides that in many granitic rocks the structure is connected with the consolidation of the magma of the rock in which it occurs. Since, however, myrmekite has crystallized within the borders of another mineral, replacing its substance, it cannot be regarded as primary in the strictest sense of the word. Where it has formed during the later stages of consolidation it is proposed to call the change *deuteric* (the term *paulopost* already used in teaching by Dr. J. W. Evans would serve equally well), as distinct from a *secondary* formation of myrmekite due to processes accompanying a later period of metamorphism.

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7. The Relation of the Titaniferous Magnetite Ores of Glamorgan, Ontario, to the Associated Scapolite Gabbros. By W. G. Foye. Econ. Geol., xi, p. 662, 1916.

THE gabbro laccolith of Glamorgan was intruded into the Grenville Series before the period of granite and nepheline-syenite intrusions described by Adams and Barlow. The latter intrusions gave off pneumatolytic gases which, according to the author, collected beneath the gabbro and slowly penetrated it. The iron and titanium carried by the gases were oxidized to titaniferous magnetite which was deposited beneath the gabbro, while the chlorine and other gases thus liberated passed on and scapolitized the overlying gabbro. The evidence put forward seems to justify the conclusion that the ores were derived from the later intrusions, and not from the gabbro itself.

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8. Are the "Batholiths" of the Haliburton–Bancroft Area, Ontario, correctly named? By W. G. Foye. Journ. of Geol., xxiv, p. 783, 1916.

THE following are the conclusions to which the author arrives:—

1. That the so-called "batholiths" were formed by the concordant injection of granite into a fissile limestone terrane.

2. That this fissility was produced by the pressure of the overlying sediments.

3. That the layers of limestones, lying between layers of molten granite, were permeated by pneumatolytic gases and fluids given off by the granite, and transformed to amphibolites or grey gneisses.

4. That the concordant injection of the granite, accompanied by the upward flow of magma at centres of intrusion, produced the dome-like character of the gneissic areas.

5. That since the term "batholithic" does not describe the true character of these areas, the term "stromatolithic" (στρωμα "a layer", λιθος "a stone") is suggested in its place.

9. On Primary Analcite and Analcitization. By A. Scott. Trans. Geol. Soc. Glas., xvi, p. 34, 1916.

In this paper Dr. Scott traces the history of the controversy that since 1890 has centred about the origin of analcite in igneous rocks. He summarizes first the arguments against the primary nature of the mineral and secondly the evidence in favour of that view. It is pointed out that there are three ways in which rocks may be modified by the action of alkali material:—

1. During an early stage in the cooling history of a magma, the liquid residuum becomes enriched in sodium-bearing molecules, so that the later portions of the pyroxenes and amphiboles are relatively enriched in that element.

2. At a late stage in the cooling history, phenocrysts already formed may be corroded by the soda residuum; felspars and nepheline are analcitized and any residual analcite that remains crystallizes out as a primary mineral.

3. At a period subsequent to consolidation the rock may be acted on by juvenile soda-silicate solutions in such a way that felsic minerals are analcitized, while mafic minerals may be recrystallized as soda pyroxene.

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *May* 2, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "Supplementary Notes on *Aclisina*, De Koninck, and *Aclisoides*, Donald, with Descriptions of New Species." By Jane Longstaff (*née* Donald), F.L.S. (Communicated by Dr. G. B. Longstaff, M.A., F.G.S.)

Since the publication of a paper by the Geological Society on *Aclisina*, in 1898, a much larger amount of material has come to hand, which has not only added to the knowledge of the species there described, but has also led to the discovery of six others new to science. The diagnoses of these are now given, and a species named by Mr. H. Bolton *Loxonema ashtonensis* is referred to this genus, as several specimens show the characteristic lines of growth.

The total number of species of *Aclisina* is now brought up to twenty-two, and there are besides several varieties. The genus is best represented in Scotland, where the specimens are generally remarkably well preserved, no less than thirteen having the protoconch intact, drawings of which show its somewhat irregular character. A table is appended giving, so far as known, the range and localities in the British Isles and Belgium. A small variety of *Aclisina pulchra*, De Koninck, appears to have continued for the greatest length of time, commencing in the Calciferous Sandstone Series, existing throughout the Lower and Upper Limestone Series and on into the Millstone Grit of Scotland.

Additional observations are also made on *Aclisoides striatula*, De Koninck, showing its variation in size and ornamentation, as well as its range throughout the Lower and Upper Carboniferous Series of Scotland, its occurrence at Settle and Poolvash, and at Tournai as well as Visé. New drawings are given of De Koninck's type-forms. One of these, as also a Scottish example, has the characteristic sinus preserved. The holotypes of the first described species were not originally selected; that omission is now rectified, with references to the collections in which they are deposited.

2. "The Microscopic Material of the Bunter Pebble-Beds of Nottinghamshire and its Probable Source of Origin." By Thomas Harris Burton, F.G.S.

As shown by the distribution of the heavy minerals, combined with (*a*) the direction of the dip in the cross-bedding, (*b*) the evidence adduced by boreholes and shaft-sinkings, a main current from the west is indicated. In the neighbourhood of Gorsethorpe this current bifurcated, one division flowing eastwards, the other running south-eastwards.

A large quantity of the material is derived from metamorphic areas, as shown by the presence of staurolite, shimmer aggregates, microcline, sillimanite, and kyanite.

The source of the bulk of the material is probably Scotland, and the westward adjoining vanished land, from rocks similar in the main to those of the metamorphic and Torridonian areas known in that country. Minor supplies came from the neighbouring Pennine ridge, and from other surrounding tracts of high land.

The material was transmitted by means of a north-western river and its tributaries, flowing into the Northern Bunter basin. During certain flood-periods this river overflowed across Derbyshire, carrying its load of sediment, much of which was deposited, as it is now found, in the Pebble-Beds of Nottinghamshire.

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2. *May* 16, 1917, at 5.30 p.m., in lieu of the usual reading of papers a lecture was delivered on "British Geological Maps as a Record of the Advance of Geology", by Thomas Sheppard, M.Sc., F.G.S. The lecture was illustrated by lantern-slides and by an important series of early maps from the Society's Collection.

Zoological Society of London.

May 1, 1917.—Dr. A. Smith Woodward, F.R.S., Vice-President, in the Chair.

The Secretary, Dr. P. Chalmers Mitchell, F.R.S., announced with the deepest regret that Mr. Henry Peavot, the Society's Librarian and Clerk of Publications, had been killed in action. Mr. Peavot had entered the service of the Society in 1896, and, after passing through various departments, was appointed Assistant Librarian and Clerk of Publications in 1908, and was promoted to the post of Librarian and Clerk of Publications in 1912. In every way he had gained the esteem and regard of the Scientific Fellows of the Society, and was one of the most valuable and competent members of the Society's staff.

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ASSISTED BY

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JULY, 1917.

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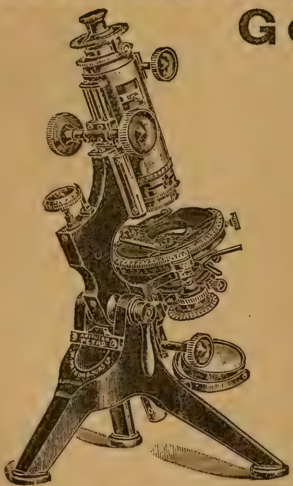

Alfred Harker

From a photograph by Elliott & Fry.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. VII.—JULY, 1917.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Alfred Harker, M.A., LL.D. (McGill), F.R.S., President of the Geological Society of London 1916–17, Fellow of St. John's College, and Lecturer in Petrology in the University of Cambridge.

(WITH A PORTRAIT, PLATE XVIII.)

DR. ALFRED HARKER was born at Hull, in Yorkshire, on February 19, 1859; his name may thus be appropriately added, as an "eminent geologist", to the county which claims amongst its sons the name of Sedgwick, the Woodwardian Professor of Geology in the University of Cambridge (1818–73), the first who taught modern geology; and famous as having had such historians as William Smith (the "Father of English Geology") and his nephew, Professor John Phillips; also as the birthplace of Sorby, Williamson, Strickland, Hudleston, and many others.

He had, as a boy, a taste for chemistry and natural history, and made his first acquaintance with geology in his holiday wanderings along the Yorkshire coast, with John Phillips' writings as his guide.

It was as a student of mathematics that Harker went up to Cambridge, and was entered at St. John's College in 1878. But he soon found, in the genial Professor McKenny Hughes,[1] one who was ever ready to welcome any "freshman" with geological leanings, and Harker became one of the first members of the Sedgwick Club, founded about that time by Watts and others of his contemporaries.

After graduating in the Mathematical Tripos as 8th Wrangler, in January, 1882, Harker came back to geology by way of physics and mineralogy, and was at once offered a teaching post on the geological staff. As demonstrator and afterwards lecturer, he has been responsible for the teaching of petrology at Cambridge for more than thirty years; but for a long time the almost total want of accommodation and equipment in the old Woodwardian Museum made it impossible to carry out this work in a satisfactory manner.

Alfred Harker was elected a Fellow of St. John's in 1885. In those days this College, owing doubtless in part to Professor Bonney's influence, was notably strong in Geology. Of the last nine Presidents of the Geological Society five have been Johnians.

As a field-geologist his earliest original work was done in North

[1] Written on May 10. Our dear friend Professor Hughes passed away on June 9; see Obituary Notice, p. 334.—Ed. Geol. Mag.

Wales, first on the cleavage structure of the slates, and then on the Ordovician igneous rocks. The results of the latter work were in part embodied in the Sedgwick Prize Essay for 1888.

From 1889 to 1893, excepting a visit to America, Harker's vacations were spent mostly with his friend and fellow-Johnian, J. E. Marr, in the Lake District. Their aim was principally to decipher the geological structure and sequence of that district in the light of what had been learnt in other disturbed areas. This problem is perhaps not to be finally solved without a complete re-survey of the ground; but some conclusions were reached, and memoirs on the Shap granite and its metamorphism and on the Carrock Fell intrusions were also among the results of those pleasant years.

In 1895, by the good offices of Sir Archibald Geikie, Harker became attached to the Geological Survey of Scotland, and was engaged for ten years in the investigation of part of Skye and of the Small Isles to the south. The summer half of the year was spent in mapping and the winter half in the study of material gathered in the field. The results of this work are contained in the official maps and memoirs, including a special memoir on *The Tertiary Igneous Rocks of Skye.*

In 1905 he quitted the Geological Survey for other engagements. The geological department at Cambridge was now housed in the new Sedgwick Museum, and teaching duties, together with the charge of the petrological section of the Museum, had become more engrossing. Dr. Harker found time, however, for frequent visits to the Highlands and other parts of Britain with occasional excursions abroad. He had made it part of his programme as a teacher of students to bring together, as far as possible, complete representative collections of rock-specimens in the Museum at Cambridge, which now possesses large series from many British areas, as well as from Norway, Canada, and other countries. The collection of rock-slices also has grown until it now numbers more than 12,000.

Dr. Harker had written in 1895, chiefly to meet the needs of his own students, a Textbook of Petrography, and this has been revised from time to time in subsequent editions. In 1909 appeared *The Natural History of Igneous Rocks*, which aimed especially at interesting geologists in the genetic aspect of petrology.

In February, 1907, on the occasion of his presenting the Murchison Medal to Mr. Alfred Harker, F.R.S., Sir Archibald Geikie, then President of the Geological Society, said: "The Murchison Medal has been assigned to you as a testimony of the Council's appreciation of the importance of your contributions to Petrographical and Structural Geology.

"You had already distinguished yourself by your studies in cleavage, by the zeal and success with which you had thrown yourself into the pursuit of petrographical research along those modern paths in which this department of our science has been so transformed and enlarged, and lastly by the skill which you had shown in the field investigation of the ancient igneous rocks of North Wales and of part of the Lake District.

"With this reputation already established and yearly growing, you were induced, at my request, to enter the Geological Survey. Although the circumstances under which you joined that service formed a new departure in its usages, I have always felt that on no part of my long connection with the Survey could I look back with more satisfaction than on the arrangements which enabled us to secure your services.

"You speedily acquired the skill of a practised surveyor, and among the hills of Skye and Rum you had an opportunity of mapping some of the most complicated and deeply interesting pieces of volcanic geology in this country. Having had from time to time opportunities of visiting you on the ground, I can bear witness both to the bodily vigour and endurance and to the geological enthusiasm and insight with which you climbed crags and peaks on which no geologist had set foot before you. The maps and memoirs which you have produced of these portions of the Inner Hebrides will always remain as a monument of your prowess as a field geologist and petrographer."

Another of his fellow-workers writes: "What specially struck me about Harker was his thoroughness. Having started on a piece of work he devoted his whole energy to its completion. All else was subordinated to its execution, and one might almost literally say that no stone was left unturned which would cast any light upon it."

"He is one of those who believe that for the right understanding of a science it is necessary to know something of the history of its growth, and with this in view he has accumulated in his library a valuable series of works which bear upon the early history of the science of geology and the more recent branch of petrography.

"Harker's time has been largely occupied by teaching and research, but he has nevertheless contrived to devote much of it to the enrichment of the petrographical collections in the Sedgwick Museum, and to their arrangement. He has travelled much to obtain specimens for this purpose. Of special interest are two magnificent collections which he has brought together to illustrate genetic connexion of igneous rocks, the one of those of Western Scotland, the other of the group rendered classic by the researches of Brögger in the Christiania region.

"Though Harker's fame rests largely on his petrographical work he is also a physical geologist of a very high order, as might be expected from one who prefaced his geological career by a mathematical training. We may make special mention of the very important contribution which he made to the physics of glacial erosion in his paper on Ice Erosion in the Cuillin Hills (Skye), which appeared in the Transactions of the Royal Society of Edinburgh, 1901 (T.R.S.E., vol. xl, pt. ii)."

In addition to his service to science, as a Lecturer in Petrology in the University, Dr. Harker has published most of the results of his investigations, whether in the field, the laboratory, or with the microscope, in a permanent form, for the use of geologists generally; and the Editor is happy to record that, of his numerous publications, fifty are preserved in the pages of the Geological Magazine.

Dr. Harker received the Wollaston Donation Fund, 1896; the Murchison Medal, 1907. He was President of Section C, British Association, at Portsmouth, 1911. He has also kept up connexion with his native county, and was President of the Yorkshire Naturalists' Union, 1911, and President of the Yorkshire Geological Society, 1912–13. The McGill University (Montreal) conferred on Dr. Harker the honorary degree of LL.D. in 1913. He is at this time President of the Geological Society of London, 1916–17, till February, 1918.

List of Dr. A. Harker's principal Geological Writings.

1884. "Graphical Methods in Field Geology": Geol. Mag., pp. 154–62.

1885. "The Oolites of the Cave District": *Naturalist*, pp. 229–32.
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"On the Successive Stages of Slaty Cleavage": ibid., pp. 266–8.

1886. "Report on Slaty Cleavage and Allied Rock Structures": Rep. Brit. Assoc. for 1885, pp. 813–52.

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1888. "Notes on the Geology of Mynydd Mawr and the Nantlle Valley": ibid., pp. 221–6.
"On some Anglesey Dykes," III: ibid., pp. 267–72.
"Additional Note on the Blue Hornblende of Mynydd Mawr": ibid., pp. 455–6.
"On the Eruptive Rocks of the Neighbourhood of Sarn, Caernarvonshire": Q.J.G.S., vol. xliv, pp. 442–61.

1889. "Notes on the Physics of Metamorphism": Geol. Mag., pp. 15–20.
"Local Thickening of Dykes and Beds by Folding": ibid., pp. 69–70.
"Eyes of Pyrites and other Minerals in Slate": ibid., pp. 396–7.
The Bala Volcanic Series of Caernarvonshire (Sedgwick Prize Essay for 1888), 8vo, Cambridge.
"Petrological Notes on Boulders from the Boulder-Clays of East Yorkshire": Proc. Yorks. Geol. Soc., vol. xi, pp. 300–7.

1890. "Petrological Notes on Some of the Larger Boulders on the Beach South of Flamborough Head": ibid., pp. 409–23.

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(With J. E. Marr.) "The Shap Granite and the Associated Igneous and Metamorphic Rocks": Q.J.G.S., vol. xlvii, pp. 266–327.
"Petrological Notes on Rocks from the Cross Fell Inlier": ibid., pp. 512–25.
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1892. "Physical Geology in the Basin of the Colorado": *Natural Science*, vol. i, pp. 205–10.
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"Porphyritic Quartz in Basic Igneous Rocks": ibid., pp. 485–8.

1893. "Norwegian Boulders in Holderness": *Naturalist*, pp. 1–4.
"The Use of the Protractor in Field Geology": Sci. Proc. Roy. Dubl. Soc. (N.S.), vol. viii, pp. 12–20.
(With J. E. Marr.) "Supplementary Notes on the Metamorphic Rocks around the Shap Granite": Q.J.G.S., vol. xlix, pp. 359–71.
"On the Migration of Material during Thermal Metamorphism": *Journ. Geol.*, vol. i, pp. 574–8.
"Extinction Angles in Cleavage-Flakes": *Min. Mag.*, vol. x, pp. 239–40.
"Berthelot's Principle applied to Magmatic Concentration": Geol. Mag., pp. 546–7.

1894. "Carrock Fell: a Study in the Variation of Igneous Rocks," I: Q.J.G.S., vol. l, pp. 311–36.
"The Evolution of Igneous Rocks": *Science Progress*, vol. i, pp. 152–5.
"Ancient Volcanic Rocks": ibid., vol. ii, pp. 48–63.
"Cordierite in the Lake District": GEOL. MAG., pp. 169–70.
"On some Variolitic Rocks on Carrock Fell": ibid., pp. 551–3.

1895. "Carrock Fell: a Study in the Variation of Igneous Rocks," II and III: Q.J.G.S., vol. li, pp. 125–47.
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"The Natural History of Igneous Rocks. I. Their Geographical and Chronological Distribution": *Science Progress* (N.S.), vol. i, pp. 12–33.

1898. "The Natural History of Igneous Rocks. II. Their Forms and Habits": ibid., vol. ii, pp. 203–18.

1899. "Glaciated Valleys in the Cuillins, Skye": GEOL. MAG., pp. 196–9.
"On the Average Composition of British Igneous Rocks": ibid., pp. 220–2.
"Notes on Subaërial Erosion in the Isle of Skye": ibid., pp. 485–91.
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"The Sequence of the Tertiary Igneous Rocks of Skye": GEOL. MAG., pp. 506–9.

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1905. "The Tertiary Crust-Movements of the Inner Hebrides": Trans. Edin. Geol. Soc., vol. viii, pp. 344–50.

1906. "The Geological Structure of the Sgùrr of Eigg": Q.J.G.S., vol. lxii, pp. 40–67.
"Cordierite in the Metamorphosed Skiddaw Slates": *Naturalist*, pp. 121–3.
"A Cordierite-bearing Lava from the Lake District": GEOL. MAG., pp. 176–7.

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1908. (With contributions by G. Barrow.) *The Geology of the Small Isles of Inverness-shire* (Mem. Geol. Surv. Scot.).

1909. *The Natural History of Igneous Rocks*, 8vo, London.

1910. *Tables for Calculation of Rock Analyses*, Cambridge.

1912. Presidential Address to Section C (Geology): Rep. Brit. Assoc. for 1911, pp. 370–81.
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1912. "Lamprophyre Dykes in Long Sleddale": ibid., pp. 266–7.
1914. "Fractional Crystallization the Prime Factor in the Differentiation of Rock-magmas": Congr. Géol. Int. Comp.-Rend., xii, pp. 205–8.
"The Sgùrr of Eigg: some Comments on Mr. Bailey's Paper": Geol. Mag., pp. 306–8.
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II.—Cretaceous Mollusca from New Zealand.

By C. T. Trechmann, M.Sc., F.G.S.

PLATES XIX AND XX.[1]

Introduction.

Owing to incomplete palæontological knowledge, the true age and correlation of the various divisions of the great Mesozoic series of New Zealand, which, together with the Maitai Series, forms such an important element in the structure of the country, has long remained a matter of uncertainty. In consequence the idea has to some extent taken hold among New Zealand geologists that the Mesozoic faunas, owing to supposed conditions of isolation, show archaic features. It was explained that certain Permian forms occurred in the Trias and that Trias forms may have persisted into Jurassic times, and to a still greater extent that a Cretaceous fauna lived on in this portion of the earth into the Tertiary period.

On going further into these questions I find no support for the theory, and in the case of the Cretaceous, a comparison of the fauna of the Senonian with corresponding faunas of Australia and especially of South America shows that the isolated survival theory is untenable. The arguments adduced in its favour apply equally well to the Cretaceous of South America and other parts of the Indo-Pacific region as they do to New Zealand.

It must be remembered that the present isolation of New Zealand as a land mass is a phenomenon of late geological time. In the Permo-Carboniferous period there was as much or more land in the Southern Hemisphere as there now is in the Northern. The Cretaceous and Tertiary faunas of New Zealand point to a much closer connexion with South America than obtains at the present day. The number of species of recent Mollusca common to the coasts of New Zealand and Tierra del Fuego is now very slight.

In a paper recently published in this Magazine[2] I showed that the Maitai Series contains a fauna which agrees, so far as it goes, exactly with that of the marine Permo-Carboniferous of New South Wales

[1] Plate XXI will appear with the second part in the August Number.
[2] "The Age of the Maitai Series of New Zealand": Geol. Mag., N.S., Dec. VI, Vol. IV, pp. 53–64, Feb. 1917.

and Tasmania, but that the Maitai beds differ from the Permo-Carboniferous of Gondwanaland in being entirely marine.

I also showed in a recent communication to the Geological Society that the Kaihiku, the lowest known Mesozoic fossil-bearing horizon in New Zealand, contains fossils of late Middle or early Upper Trias, and is not as was formerly supposed of Permian age, and that the Carnic, Noric, and Rhætic horizons of the Upper Trias are well represented.

The Jurassic still remains the greatest *terra incognita* in New Zealand palæontology, and owing to the discontinuous nature of the outcrops, the scarcity and indifferent state of preservation of the fossils, its study will involve some difficulty. Several horizons seem to be represented by the fossils, of which I have a considerable collection. A knowledge of the Jurassic horizons which occur in New Zealand is an important matter, because the determination of the highest Jurassic and the lowest Cretaceous beds will indicate the time limits during which New Zealand first became a land surface.

It now seems to me quite clear that the New Zealand continent, and the present New Zealand is the relic of a former land mass both of continental dimensions and of continental faunal character, originated some time about the period of the final fragmentation of Gondwanaland. I am also inclined to think that its compression and uplift are among the phenomena of readjustment consequent upon that event.

The Cretaceous rocks form the basal portion of the newer or covering series, and where they occur they rest, as in Chili and the Californian coast ranges, with a most pronounced unconformity on the denuded edges of the folded and in part metamorphosed rocks beneath them. The lowest Cretaceous marine horizon present will afford us knowledge when the sea began once more to transgress upon the margins of the old peneplaned and lowered land mass which had arisen and been partly denuded during the period intervening, so far as we know at present, between very late Jurassic and Upper Cretaceous times.

The outcrops of the Upper Cretaceous beds in New Zealand are well shown by Professor J. Park on a small-scale map.[1]

They occur in six or seven more or less isolated patches of greater or less extent. The relations of the Cretaceous to the overlying Tertiary series have given rise to much discussion, into which however I do not propose to enter in the present paper.

On the eastern side of the Alpine chain in the middle part of the South Island, in the Waimakariri and Waipara gorges, the marine Upper Senonian rests on the upturned edges of the older rocks. This condition of things obtains also at Quiriquina, on the coast of Chili. In the north-eastern part of the South Island and apparently also on the eastern side of the North Island some earlier Cretaceous beds with *Inoceramus* occur. In this connexion it is important to notice that in South Patagonia, between Lago Argentino and Last Hope Inlet, on the eastern side of the Cordillera, the Upper Senonian rests on beds containing *Inoceramus Steinmanni*,

[1] *The Geology of New Zealand*, 1910, sketch-map.

Wilckens, which are Upper Cretaceous but probably still of Senonian age.

The faunal and stratigraphical details in New Zealand still remain to be worked out, especially in the North Island, but the facts already known point to a north to south as well as to an east to west transgression of late Cretaceous beds, with a further overstep of the Upper Senonian to the south-west across the earlier upper Cretaceous beds beneath them. Mr. H. Woods has recently examined some Cretaceous fossils belonging to the New Zealand Survey collections and concludes that two distinct faunas occur.[1] The older of these occurs at Coverham, in the middle Clarence Valley in the north-east corner of the South Island, and is of approximately Upper Greensand or Gault age. The younger fauna of Upper Senonian age occurs at Amuri Bluff on the north-east coast of the South Island, at Selwyn Rapids, and other localities.

I understand that only the Lamellibranchs of Selwyn Rapids were examined by Mr. Woods. His work, however, is not published yet. Professor P. Marshall has recently investigated a very interesting and rather extensive fauna which occurs at Wangaloa, on the south-east coast of the South Island south of Dunedin. It is clearly newer than the Upper Senonian faunas above-mentioned, but must, on account of the presence of *Pugnellus*, in my opinion, still be referred to the Cretaceous. I should regard it as Danian or Maestrichtian.

The object of the present paper is to describe a series of fossils other than the groups already described by Mr. Woods or those at present under description by Professor Marshall, which throw further light on the age and correlation of some of the Cretaceous beds of the South Island of New Zealand.

All the specimens described were collected by myself, so I can guarantee the accuracy of the localities and horizons.

The Localities.

Selwyn Rapids.

This locality is situated at the base of the eastern foothills of the Southern Alps about 36 miles west of Christchurch. The railway station is Glentunnel, and the outcrop forms a series of rapids in the Selwyn River about a mile from the station. The beds consist of a series of glauconitic greensands more or less concretionary. In the bed of a tributary creek a few hundred yards away there are several enormous spherical concretions[2] 5 or 6 feet in diameter

[1] *Nature*, March 22, 1917, p. 79.

[2] Similar concretions occur at Hampden, in North Otago, in beds apparently of the same age that crop out on the seashore. The concretions are surrounded by a casing of stony material in which the finest cone-in-cone structure I have ever seen is developed. The apices of the cones as a rule are directed towards the centre of the nodule, and the bases of the cones on the outside assume forms that suggest floral structures. The outer skin of the septaria is a few inches thick and is generally loose and detached from the concretion and is easily broken off. This together with the presence of yellow calcite veins which pass in all directions through the septaria suggests that the cone-in-cone structure is connected with a contraction of the inner portion of the septarian concretions. These large septarian nodules are rather sparingly distributed in

that show sections of *Conchothyra* and other fossils on the weathered surfaces. These concretions are extremely hard in places.

At the Rapids the fossils are very badly preserved in the softer rock, but the harder portions exhibit many sections of well-preserved fossils on the waterworn surface, but the rock is so hard that a hammer and chisel are of little use. On one visit, however, I employed a man to put some half-dozen shots of gelignite into the most likely-looking places, with the result that a large quantity of rock was broken up and became available for collecting.

The fossils show some unequal distribution in this bed, and *Conchothyra*, *Aplustrum*, and other forms occur in little clusters or nests. Lamellibranchs and Gasteropods are the chief fossils, but scales and bones of fish also occur, the former rather plentifully. I was fortunate in obtaining two Ammonites and a Belemnite, neither of which seems to have previously been recorded from this locality, and which establish the Mesozoic age of the beds beyond question. I collected a large number of Lamellibranchs, but as Mr. Woods has described those of the old Survey collection from this locality I await the appearance of his memoir before I describe them or record any new forms there may be among them.

Waipara Gorge.

In the Waipara Gorge, about 35 miles north of Christchurch, there is a glauconitic sandstone full of marine shells a very short distance above the local base of the Cretaceous and below the well-known concretionary greensands with Saurian bones. Some of the fossils are very much rolled, as though it had been an old shore-line, but unfortunately they are badly preserved. *Ostræa* is very plentiful, and there are many specimens of a shell I took to be *Conchothyra parasitica*, but which turns out to be an apparently undescribed form of *Pugnellus*. The Waipara Gorge affords the most important continuous section in New Zealand of the Cretaceous and Tertiary beds.

Waimakariri Gorge.

This locality is about 40 miles west-north-west of Christchurch. The station is Kowai Bush, and a section of Cretaceous beds resting unconformably on semi-metamorphic greywackes and argillites of uncertain age is exposed in a deep gorge of the river. The fossiliferous band is not far above the junction, and consists of some 3 feet of glauconitic greensand crowded with *Conchothyra parasitica*, the only other fossil being an occasional badly preserved valve of *Trigonia Hanetiana*.

Wangaloa.

This locality is on the coast about 35 miles south-west of Dunedin, and forms part of the Kaitangata Coalfield. Fossils occur in a calcareous sandstone with some glauconite. Professor Marshall has

a bed of blackish-grey calcareous shale which shows no trace of cone-in-cone structure. I noticed in some places that where the concretions had been affected by subsequent pressure in the bed the action of the pressure tended to obliterate again the cone-in-cone structure in the outer layer of the nodules.

recently shown that the fauna here is distinct from the usual Cretaceous such as occurs at Selwyn Rapids, and that a shell which occurs here and was formerly supposed to be *Conchothyra parasitica* is really a new species of *Pugnellus*. Neither Ammonites nor Belemnites have yet been found in this bed. Marshall has recently published[1] a provisional list of fifty-two species of Mollusca from this locality which seems to include a considerable number of Tertiary Oamaru forms and even some recent species. He is at present investigating this fauna more closely. I made a fairly large collection one day at this locality, but I await Professor Marshall's work before reporting on them.

Palæontology.

Trigonia cf. Hanetiana, d'Orb. (Pl. XXI, Fig. 5.)

Voyage dans l'Amérique Paléontologie, 1842, p. 127, pl. xii, figs. 14–16.
Philippi, Die quatären und tert. Versteinerungen Chiles, 1887, p. 199, pl. xlii, figs. 1–3.
Steinmann, "Die Gastropoden u. Bivalven der Quiriquina-Schichten": N.J. für Min., Beilage Bd. x, p. 101, pl. vii, figs. 8, 9, 1895.
Hector, Catalogue Ind. and Col. Exhibition, 1886, p. 64, fig. 5, *Trigonia sulcata*.

The only other shell I saw in the *Conchothyra* bed in the Waimakariri Gorge was a *Trigonia*, which occurred as single valves in a friable and fragmentary condition. I collected the pieces of one and succeeded in joining them together. It is undoubtedly the shell that Hector illustrates without any description under the name *Trigonia sulcata*. The curious double sculpture on the anterior part of the shell makes this quite certain. Steinmann notices Hector's figure, and compares it with *T. Hanetiana* from Quiriquina, in Chili, and remarks "that of all known forms of *Trigonia* the only one which compares with *T. Hanetiana* is one illustrated by Hector under the name *T. sulcata* from the lower (*sic*) Cretaceous of New Zealand. Both forms are obviously very closely related and represent a genuine Pacific form, for which it would be best to institute a special group". He goes on to say that it does not fall well into any of Lycett's *Trigonia* groups.

My specimen is a right valve, and unfortunately lacks the hinder part, but enough remains to give a fair description of it. The beak is rather anterior and the shell considerably elongated behind. The ridge which passes from the beak to the hinder part is bluntly angular, the sides making nearly a right angle with one another, and in front there is a wide shallow groove almost devoid of sculpture. Between this and the rounded anterior margin the surface is ornamented with broad and shallow concentric growth grooves which are crossed obliquely by a series of about six broad and low ridges, which are arranged parallel to the main posterior ridge and gradually diverge and increase in size as they pass from the upper anterior part of the shell backwards to the lower margin. Where they are strongest they tend to obliterate the concentric grooves of growth. The teeth cannot be seen. Height 50 mm.

[1] "Relations between Cretaceous and Tertiary Rocks": Trans. N.Z. Inst., vol. xlviii (new issue), p. 114, 1915.

I am inclined to think the New Zealand shell is identical with *T. Hanetiana*, but owing to the poor condition of the only specimen I collected I cannot be quite certain.

Wilckens[1] describes another form, *T. ecplecta*, from the Upper Cretaceous of Baguales in South Patagonia, which, though larger, is certainly related to *T. Hanetiana*, but on which the cross ribs are confined to the upper anterior portion of the shell, and the concentric furrows are much stronger.

T. Hanetiana belongs to the commonest fossils of the Chilian Upper Cretaceous, and together with *Cardium acuticostatum*, d'Orb., is regarded as a leading fossil of the Quiriquina Beds.

I found no Trigonias at Selwyn Rapids, but I believe they occur there.

DENTALIUM sp. (Pl. XXI, Fig. 10. × 2 nat. size.)

Shell slightly curved, increasing slowly in size, rather thin, and almost circular in section. The surface is rather rough, and the growth-lines are well marked. A specimen I collected resembles *D. Chilensis*, d'Orb., which is common at Quiriquina, but is without the longitudinal striæ that occur on the thin end of that species. It is comparable also with *D. Cazadorianum*, Wilckens, from South Patagonia.

Locality.—Selwyn Rapids. Dentaliums of fairly large size are common, generally as casts in some parts of the rock.

TURRITELLA sp. (Pl. XIX, Fig. 11. × 2½ nat. size.)

Shell small, consisting of seven whorls, which increase very gradually. The test is rather thin, the sutures are shallow, and each whorl is decorated with seven or eight very faint spiral raised ridges.

Locality.—Selwyn Rapids.

CHRYSOSTOMA SELWYNENSIS, sp. nov. (Pl. XXI, Figs. 4*a*, *b*.)

Shell very small, thick, and globose, consisting of five whorls. Surface smooth and rounded, sutures shallow. There is a faint umbilicus which is more or less covered by a reflected callus extension of the inner lip. The outer lip, though broken, seems to have been sharp. Height 5 mm. I can find no described form in the Indo-Pacific Cretaceous resembling this small and insignificant-looking shell, and so am constrained to give it a new specific name. The only living representative of the genus to which it certainly seems to belong is a beautiful shell, *C. paradoxum*, Born, found on the shores of New Caledonia.

Locality.—Selwyn Rapids, one specimen.

NATICA (EUSPIRA) VARIABILIS, Moore. (Pl. XIX, Figs. 8–10.)

Charles Moore, Quart. Journ. Geol. Soc., vol. xxvi, p. 256, pl. x, fig. 15, 1870.
Jack & Etheridge, Geol. and Pal. Queensland, 1892, p. 485, pl. xxxi, figs. 2, 3.
R. B. Newton, Proc. Malac. Soc., vol. xi, pt. iv, p. 232, pl. vi, figs. 21–3, 1915.

The New Zealand form of this Australian fossil is rather variable. One specimen (Fig. 8) has four volutions, is broader than it is high,

[1] Berichte der Naturf. Gesell. z. Freiburg, Bd. xv, p. 37, pl. vii, figs. 2, 3, 1907.

and is rather depressed. The body-whorl is large and globose and increases rapidly in size. The surface is rather eroded and bears closely spaced rather foliaceous growth-lines. The suture is somewhat deep and the whorls are not flattened below it, and there are no parallel striæ on the basal part of the body-whorl. It measures 16 mm. high and resembles a specimen figured by Jack & Etheridge, pl. xxxi, fig. 2. Another specimen (Fig. 9) differs in having a more elevated spire, the suture is not insunken and the whorls are flattened just below it, and the body-whorl is relatively smaller and less swollen. About six fine rounded concentric ridges occupy the base of the body-whorl near the umbilicus, and the growth-lines are much less strongly marked than in the first variety. It is smaller in size and resembles the specimen figured by Jack & Etheridge, pl. xxxi, fig. 3. Another smaller specimen (Fig. 10, × 1½ nat. size) resembles the last, but the concentric ridges occupy the whole of the body-whorl.

This shell agrees in every way with the Australian form, and is the only Australian Cretaceous fossil I found in the New Zealand rocks. Mr. R. B. Newton has recently discussed the generic affinities of this shell in a paper quoted above dealing with the fossils of the opal deposits of the interior of New South Wales.

It occurs in the Rolling Downs Formation of the Lower Cretaceous, and also in the Desert Sandstone, Upper Cretaceous, in Australia. I have a specimen from the opal deposits of Whitecliffs, New South Wales.

Locality.—Selwyn Rapids, where it is not scarce. I did not find it in any other locality, and this is the first record of the occurrence of this typically Australian form in New Zealand and forms the sole connecting link among my specimens with the Australian Cretaceous.

NERITOPSIS (?) SPEIGHTI, sp. nov. (Pl. XIX, Figs. 12–15.[1])

The shell consists of four or five whorls, and in young specimens is thin and oval in shape. In the adult state it is more rounded owing to flattening of the spire and rapid enlargement of the body-whorl. The spire in immature specimens is pointed and rather elevated, but in the adult specimen it is flattened through erosion or wear. In the largest example there is a faint umbilicus, the peristome is entire, and the inner lip is somewhat detached from the body-whorl. The lip is thickened for some distance back from the margin, but ends in a sharp rim. The body-whorl is decorated with about fifteen raised concentric parallel rounded ridges, alternating with furrows of about the same width and depth. On the earlier whorls the furrows are less strongly marked. The growth-lines are rather faint, but are interrupted here and there on the body-whorl by a strong furrow.

In the absence of knowledge of the operculum or of the animal it is impossible to fix with certainty the genus of this shell, as many genera quite unallied to one another develop parallel concentric furrows, such as *Cinulia*, *Dolium*, *Pyrula*, *Fossarus*, and many others.

The moderate thickness of the shell and increasing thickness of the adult lip and sharpness of the aperture point to *Neritopsis*

[1] Fig. 15 is × 2 nat. size.

as being the most likely genus. It also resembles *Vanikoro*, but the shell seems too thick and the inner lip too strongly developed. The partial detachment of the inner lip from the body-whorl and the complete peristome suggests the genus *Fossarus*, which together with *Vanikoro* has a horny operculum, whereas that of *Neritopsis* is thick and stony. There is no trace of columellar folds nor of a reflected lip which might connect it with *Cinulia* or *Eriptycha*.

The erosion or battering which the spire has suffered in the adult specimen points to its being some shore-loving form, but whether of the Littorinidæ or Neritopsidæ is uncertain, but I think the genus *Neritopsis* is the more likely one.

Locality.—Selwyn Rapids.

The only species I can trace which at all resembles the present form is *Vanikoro Kiliani*, Wilckens,[1] which occurs at Snow Hill and Seymour Island in Antarctica. But this is a very small shell and consists only of three to four whorls and has fourteen spiral ribs, the spaces between which are not always equal and the ribs are preserved only on the last whorl. I take the opportunity of naming this shell after my friend Dr. R. Speight, director of the Christchurch Museum, who has published many papers on New Zealand Geology, and who assisted me to collect several of the Cretaceous fossils.

CONCHOTHYRA PARASITICA, McCoy. (Pl. XX, Figs. 4, 5.)

Hector, Cat. Ind. and Col. Exhib., 1886, p. 58, fig. 4.
Park, Geol. New Zealand, 1910, p. 90, pl. v (after Hutton).

This extraordinary Gasteropod is the most abnormal of the curious group of the Pugnellids. The smooth callosity of the inner lip is more exaggerated than in any other species of the group, and in some specimens it extends beyond the apex and sometimes almost buries the spire. The thickened claw-like outer lip is very large and heavy, and the growth-lines and ridges on the body-whorl are very exaggerated.

If the genus *Conchothyra* is to be retained—and in view of its frequent mention in New Zealand geological literature and the great specialization of the shell in question I think it should be—it may be re-defined as follows:—

Shell as in *Pugnellus*, but the early whorls are smooth and devoid of nodes or ribs. Spire short and in fully grown specimens almost buried by the labial callosity, and often scarcely visible owing to erosion. The lines and ridges of growth are coarse and prominent on the last whorl. The anterior channel of the mouth is deep and narrow, the posterior channel is shallower and more or less semi-circular in shape. The outer lip is much thickened and often greatly prolonged.

I think this curious mollusc may have been of a sluggish character and have lain partly buried in sand. Both the great weight of the shell and its frequent erosion suggest this mode of life. That part of the body-whorl on the back below the spire is generally very thin,

[1] "Die Anneliden, Bivalven, u. Gasteropoden der antarktischen Kreide, 1910": Wissensch. Ergebnisse der Schwed. Sudpolar Exped., p. 77, pl. iii, figs. 28*a*, *b*.

apparently by absorption or erosion. In one of my specimens there is a small *Anomia* attached to the surface near the inner lip which suggests that the shell may have lain mouth upwards in the sand.

Locality.—In the Upper Waimakariri Gorge there is a bed about 3 feet thick not far above the local base of the Cretaceous almost made up of thousands of these shells, some perfect and others broken. They show considerable variation in the degree of growth of the shelly callosity and the extension of the lip. The only other fossil that I found associated with them in this locality were a few valves of *Trigonia Hanetiana*, d'Orb. At Selwyn Rapids the shell is less plentiful, and is better preserved in the harder parts of the rock, but is in all respects similar to the specimens at Waimakariri.

It seems, as one might expect in so specialized a shell, to have a restricted vertical range, and may be regarded as a characteristic fossil of the Upper Senonian.

This form is apparently quite absent from the higher Wangaloa Beds, where it is replaced by a beautiful shell recently described by Professor Marshall as *Pugnellus australis*.

Pugnellus Marshalli, sp. nov. (Pl. XIX, Figs. 1–4.)

The shell consists of six whorls, the last one large and inflated. Above the middle of each whorl there is a row of blunt nodes, and below these on the last whorl a row of smaller and less prominent nodes which in some specimens coalesce into a raised ridge. The sutures are shallow. The outer layer of the shell bears very fine concentric raised lines.

The lip is not developed to the exaggerated extent it is in some forms of *Pugnellus*. The outer lip is extended and swollen, and ends in a rounded claw-like protuberance which is very easily broken off. Anteriorly there is a channel, but the shell is not drawn out. Posteriorly there is a wide semicircular channel formed by the swollen lip of the shell. The callosity of the inner lip reaches in most specimens to the top of the third whorl from the mouth, and in one or two examples it extends above this nearly to the apex. It is a shell of moderate size, the height being about 26 mm.

This shell was formerly erroneously supposed to be a *Struthiolaria* or *Pelicaria*, and a specimen was recently identified as such by Mr. Suter, and Prof. Marshall[1] remarks that it is the first occurrence of the essentially Tertiary form *Struthiolaria* in Cretaceous rocks.

I obtained, however, nine or ten perfect examples with entire lips and can definitely say that it is a true *Pugnellus*. It often happens that the specimen is immature or the lip is missing when the sculpture on the earlier whorls of the shell certainly recalls that on the recent *Pelicaria*. However, in no *Struthiolaria* that I have seen does the labial callosity extend to beyond the lower half of the penultimate whorl. The same remark applies to *Pelicaria*, which has in addition a thin smooth shelly deposit covering the back of the last and penultimate whorl. Neither *Struthiolaria* nor *Pelicaria* has the thickened and swollen outer lip characteristic of *Pugnellus* which is so conspicuous in the present shell.

[1] Trans. N.Z. Inst., vol. xlviii, p. 118, 1915.

Locality.—Selwyn Rapids, where it is rather common.

I name this species after Professor P. Marshall, who has done so much in elucidating the geology of New Zealand and in calling attention to the problems of the Cretaceo-Tertiary question in the South Pacific region.

Pugnellus Waiparensis, sp. nov. (Pl. XX, Figs. 1*a*, *b*.)

The spire is moderately elevated and the shell consists of six whorls. The shell is almost completely overgrown up to the summit of the spire with a platy extension of the lip, and only when this is broken away is the spire visible and the nodes and ornamentation of the whorls seen. The earlier whorls are decorated with folds which develop into elevated and rather sharp nodes. These are placed in a diagonal position on the shell rather above the suture on the penultimate whorl, and are faintly visible on the body-whorl where they occur above the median line. Below these nodes on the last whorl there is a blunt faintly raised ridge.

A series of fine, rather wavy, spiral, raised lines occur on the penultimate whorl and are faintly seen on the body-whorl below the ridge. They run somewhat irregularly and are not exactly parallel to one another, but approach and recede again, a peculiarity already noticed by Wilckens in the case of *Pugnellus Hauthali*,[1] which he describes from South Patagonia. The anterior channel of the lip is not produced, and the outer margin of the lip is not swollen to an unusual extent for a *Pugnellus*.

This shell approaches *P. Hauthali* in having the spire completely covered with a leafy shell growth and in the diagonal arrangement of the elongated and sharp nodes and in the curious non-parallel arrangement of the spiral lines. It differs in the spire being more elevated and the anterior channel not being elongated and the outer lip being less swollen and extended.

Locality.—Waipara Gorge, in beds with *Ostrea* near the local base of the Cretaceous and well below the Saurian concretionary beds. It occurs plentifully, but often rolled and poorly preserved. It has hitherto been mistaken for *Conchothyra parasitica*, and I thought it was a small variety of that shell, but I find on developing my specimens that it is a *Pugnellus* that I cannot identify with any described form. I found no *Conchothyra* in the bed in which it occurs.

Pugnellus australis, Marshall; variety. (Pl. XX, Figs. 2*a*, *b*.)

Trans. N.Z. Inst., vol. xlviii, p. 120, pl. xi, figs. 1–3, 1915.

Professor Marshall has recently described a highly decorated shell which occurs rather commonly at Wangaloa. When I visited that locality in his company I collected several examples of the shell, two of which, when developed, prove to be excellently preserved. One of them closely resembles his type-specimen, Fig. 2, but the other differs in having a much more exaggerated development of the lip than any of his three figured examples and is apparently an aged specimen.

[1] Berichte der Naturf. Gesell. z. Freiburg, Bd. xv, p. 18, pl. iv, figs. 2*a*, *b*, 1907.

The spire is almost concealed, and the callosity extends far beyond it and is produced into a finger-like process which is bent away from the spire. The outer lip is much thickened and produced upwards, and the interior portion of the lip is provided with a second channel through excessive growth of the callous margin. I think this variety, Figs. 2*a*, *b*, is sufficiently distinct to warrant its illustration for comparison with the more normal type, Figs. 3*a*, *b*, and to complete the illustration of the Pugnellid shells which have so far been found in New Zealand.

Locality.—Wangaloa. Maestrichtian (?).

Alaria Suteri, sp. nov. (Pl. XIX, Fig. 5. × 1½ nat. size.)

The shell consists of eight whorls which increase gradually in size. The lip of the last whorl is moderately expanded to a simple curved outline and is not digitate. It ends anteriorly in a blunt termination beneath which there is a shallow channel. The posterior margin of the lip does not seem to be channelled, and the labial expansion extends about half-way up the penultimate whorl. The whorls are decorated with rather widely spaced curved ribs, recalling those of *Scalaria* or of the recent *Aporrhais occidentalis*, Beck. On the last whorl these ribs reach from the suture to rather beyond the middle line, where they meet a blunt ridge. The whole surface of the outer layer of the shell is covered with very fine parallel raised concentric lines which continue over the ribs. Length about 35 mm.

The earlier whorls of this shell strongly recall those of a *Scalaria*, and resemble a fragment of six whorls from Quiriquina that Wilckens illustrates[1] under the name *S. araucana*, Phil., only that the varices are rather closer together than they are on the New Zealand shell.

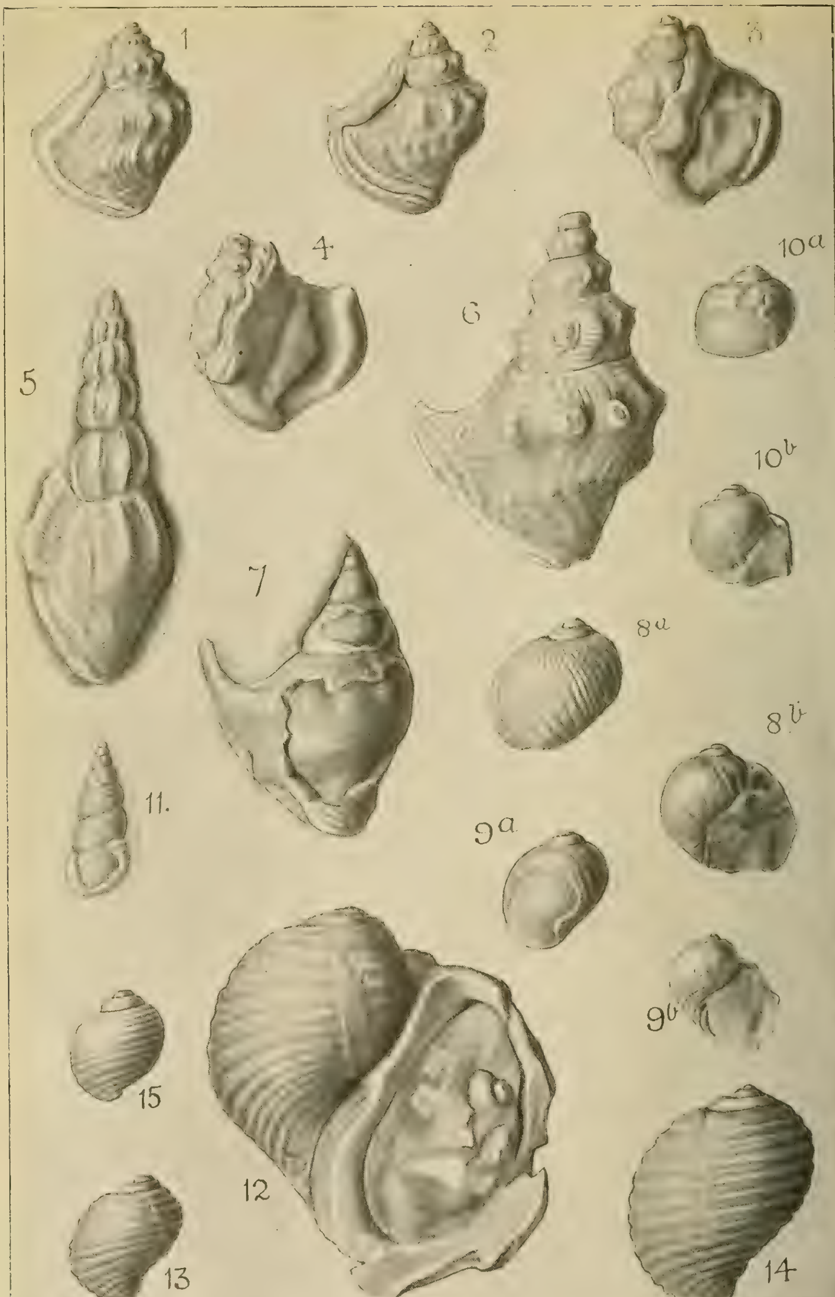
Locality.—Selwyn Rapids. I name this species, which I cannot identify with any described form, after Mr. H. Suter, of Christchurch, the leading authority on the recent Mollusca of New Zealand.

Aporrhais gregaria, Wilckens. (Pl. XIX, Figs. 6, 7.)

Berichte der Naturf. Gesell. z. Freiburg, Bd. xv, p. 16, pl. iii, figs. 10–13; pl. iv, fig. 1, 1907.

The shell consists of seven or eight whorls, the last one of which is swollen and expanded. The margin is channelled anteriorly and is not digitate, but extends to a rather sharp projection, which is produced backwards in a direction almost parallel with the spire. Between this projection and the body of the shell the lip has a broad shallow posterior channel. The shell is ornamented with a line of nodes which occur rather above the median line of the last whorl. Beneath them on the last whorl there is a series of much smaller and more numerous nodes that tend to coalesce into a raised ridge. The surface is decorated with a series of more or less continuous parallel raised ridges which are most apparent above the nodes on the penultimate whorl and on the lip. Growth-lines are rather prominent and irregular especially on the last whorl.

[1] N.J. für Min., Beil. Bd. xviii, pl. xviii, fig. 1, 1904.



G. M. Woodward, del. *Bale & Sons, imp.*

UPPER CRET EOUS GASTEROPODA, NEW ZEALAND.

G. M. Woodward, del. Bale & Sons, imp.

UPPER CRETACEOUS GASTEROPODA, NEW ZEALAND.

I am fortunately able to identify this form with certainty with the above shell, which Wilckens describes from Cazador, Sierra Contreras, and other places in South Patagonia between Lago Argentino and Last Hope Inlet. He illustrates several examples and says that the species is one that does not compare closely with any other *Aporrhais* known to him.

Locality.—Selwyn Rapids. I collected two specimens with spire and lip, one of them in fine condition which required to be laboriously chipped out and pieced together again. The spire in the better specimen (Fig. 6) is rather higher and more tapering than in the other. The shell that Hector[1] figures under the name *Rostellaria Waiparensis* is probably intended to represent this species.

EXPLANATION OF PLATES XIX AND XX.

All figures natural size unless otherwise indicated. All except *Pugnellus australis* are of Upper Senonian age.

Plate XIX.

Figs.

1–4. *Pugnellus Marshalli*, sp. nov. Selwyn Rapids.
5. *Alaria Suteri*, sp. nov. Selwyn Rapids. × 1½ nat. size.
6. *Aporrhais gregaria*, Wilckens. Selwyn Rapids.
7. Ditto, another specimen showing upward extension of the lip. Selwyn Rapids.
8–10. *Natica* (*Euspira*) *variabilis*, C. Moore. Selwyn Rapids. Fig. 10 is × 1½ nat. size.
11. *Turritella* sp. Selwyn Rapids. × 2½ nat. size.
12–15. *Neritopsis* (?) *Speighti*, sp. nov. Selwyn Rapids. Fig. 15 is × 2 nat. size.

Plate XX.

1*a*, *b*. *Pugnellus Waiparensis*, sp. nov. Waipara Gorge.
2*a*, *b*. *Pugnellus australis*, Marshall, variety. Maestrichtian (?). Wangaloa.
3*a*, *b*. *Pugnellus australis*, Marshall, normal form. Wangaloa.
4. *Conchothyra parasitica*, McCoy. Waimakariri Gorge.
5. Ditto, same locality. Another specimen.

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

III.—Some Tertiary Dykes of the Clyde Area.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology, Glasgow University.

Introduction.

The very numerous Tertiary dykes of the Clyde islands (Arran, Bute, and the Cumbraes), and of the adjacent mainland and peninsulas, have been little studied either from the geological or petrographical point of view; but they are of great interest, not only in themselves, but as providing a link between the dykes of the better known areas of the North of England, and of Skye and Mull. The material is not yet gathered on which could be based a complete account of the series. The present paper is designed to present a full description of a hitherto unrecognized type of Tertiary dyke, typically exposed in the Great Cumbrae, and to indicate its relationships to other types already described from Mull and the North of England. Furthermore, a few other dykes from the Clyde area, all of basaltic composition, will be briefly described.

[1] Cat. Ind. and Col. Exhibition, 1886, p. 58, fig. 3.

The dykes of Arran have been the subject of geological inquiry since the beginning of the nineteenth century (Harker, 1903, Bibliography, pp. 181–90 [1]). Their extraordinary abundance has attracted much attention, but little is as yet known of their petrographical characters. Still more is this the case in regard to the Tertiary dykes of Bute, the Cumbraes, and the Ayrshire and Argyllshire mainland. Sir A. Geikie has gathered together all that was previously known of the geological and petrographical characters of the Tertiary dykes, and has supplemented it with the facts gained during his own numerous traverses of the Tertiary volcanic districts (1897, pp. 118–80). He distinguishes the great solitary dykes (e.g. the Cleveland dyke of the North of England) from the gregarious dykes, which are shorter, narrower, more basic, than the solitary dykes, and are closely crowded together in restricted areas. Petrographically he divides them into four groups—(1) normal basalts and dolerites; (2) andesites; (3) trachytes (Cowal); (4) acid dykes, felsite, quartz-porphyry, pitchstone, etc., which are arranged in the order of age. The first group, basalts and dolerites, include by far the greater number of the dykes, especially those of the gregarious type, whilst the great solitary dykes generally belong to the second group, the andesites.

The Geological Survey memoir on Cowal (1897, pp. 126–71) contains abundant geological information as to the Tertiary dykes of that part of the Argyllshire mainland bordering the Firth of Clyde. Sir J. J. H. Teall's petrographical descriptions of some of these dykes suggest relationships to the Cumbrae dykes described later in this paper.

The Tertiary igneous rocks of Arran, South Bute, and the Cumbraes are the subject of a chapter by Dr. A. Harker (1903, pp. 103–27) in the Geological Survey memoir on that area. In this chapter the Tertiary dykes are briefly treated under the headings dolerite and basalt, augite-andesite, pitchstone, and devitrified pitchstones. One or two Arran dykes with special characters have been previously described by me (Tyrrell, 1913, 1916); and Dr. W. R. Smellie (1916) has recently described some of the Tertiary dykes of Bute.

The Cumbrae Type of Tertiary Dyke (*Cumbraite*).

The Great Cumbrae is traversed by several large and finely exposed Tertiary dykes of a peculiar petrographical character and striking macroscopic appearance. They consist of a black glossy rock, with a tendency to vitreous lustre, in which are embedded numerous phenocrysts of white or yellow, fresh, plagioclase felspar, which proves to be near anorthite in composition. In the field they form prominent wall-like exposures trending to the N.N.W., upon the lowest raised beach which encircles the island. The Lion Rock, near Keppel Pier, is one of these dykes which has been broken in such a way that its profile suggests a couchant lion. It rises to a height of 15 feet, with a thickness of 16 feet, whilst a second dyke

[1] See list of references at end of paper.

adjacent to the Marine Biological Station at Millport attains a height of 30 feet above the raised beach, and averages 20 feet in width. The exposure from which the type-rock has been taken occurs on the raised beach at Eerie Port on the north-west side of the island. This dyke is 29 feet wide, has a N.N.W. trend, and a slight hade to the W.S.W. Its central part has locally a more vitreous lustre or pitchstone-like appearance than other parts. Petrographical examination shows that this appearance is not due to greater richness in glass, but to its slightly fresher character. All parts of the dyke show small cavities partly or wholly filled with bitumen. This dyke can be traced inland for about a mile, which is about as far as the Lion Rock and the Marine Biological Station, where dykes can also be traced. Other and smaller dykes of the same character occur around the shores of the island.

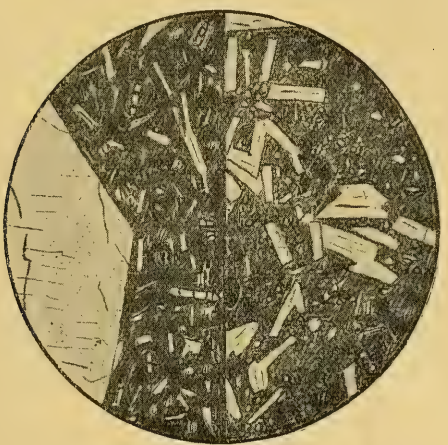


FIG. 1*a*.—Cumbraite, N.N.W. dyke, Eerie Port, Great Cumbrae. × 20. Large phenocryst of anorthite; groundmass: laths of labradorite, enstatite, augite, in base of dark glass.

,, 1*b*.—Cumbraite (Eskdalemuir type), W.N.W. dyke, Waterhead Burn, Muirkirk, Ayrshire. × 20. Microphenocrysts of labradorite and magnetite; groundmass: felspar microlites, grains of augite and enstatite, in base of dark glass.

Under the microscope (Fig. 1*a*) these rocks show phenocrysts of plagioclase near anorthite, in a groundmass of laths of acid labradorite ($Ab_1 An_1$), enstatite, augite, and abundant glass. The phenocrysts are extraordinarily fresh, with both Carlsbad and albite twinning usually well developed. They may reach a diameter of 1 cm. Twinning, cleavage, and refractive index methods agree in determining the composition of the felspar as between $Ab_{15} An_{85}$ and $Ab_{10} An_{90}$, i.e. anorthite near bytownite. The mineral, moreover, has a negative optical character which agrees with this determination. All the crystals have a narrow border of optically positive labradorite

(Ab_1 An_1). The contact between the two felspars is remarkably sharp, giving a well-marked "bright line" effect. The marginal labradorite has the same width whatever the size of the phenocryst, and has a very ragged, crenulated, or spiky margin against the glass of the groundmass, as though the glass had penetrated along the cleavage cracks. The anorthite phenocrysts carry numerous globulitic inclusions and "negative crystals" of dark glass extended parallel to 010. These are zonally arranged or confined to the centres of the crystals. The groundmass shows labradorite laths and pyroxene prisms embedded in a dark glass, the crystalline and glassy matter being about equal in bulk. The felspars form elongated laths, with bifid or trifid terminations, and a maximum extinction angle of 28 degrees, indicating acid labradorite (Ab_1 An_1). The chemical analysis shows that the orthoclase molecule must be present, but it does not appear in crystalline form, and must be incorporated in the glass.

The pyroxene includes both enstatite and augite, which are usually intergrown in characteristic fashion, with the augite always occurring on the margins. A common appearance is of three prisms in parallel position, two of augite on the margins, and a stout crystal of enstatite occupying the centre. Frequently, however, the enstatite occurs without the flanking augites, especially in the other Cumbrae dykes. It then carries minute specks of magnetite in a marginal zone. It is quite fresh, colourless, with straight extinction, positive sign, and has the heavily outlined cross-fracturing often seen in the orthorhombic pyroxenes. The augite is also colourless and has an extinction of 36 degrees.

The apparently dark-brown or black glass of the groundmass may be resolved under a high-power objective into a colourless or pale-yellow glass darkened by innumerable black globulites. It also carries numerous curved felspar microlites, and little strings of iron-ore granules which may represent original microlites of pyroxene. The apparently more glassy part of the Eerie Port dyke differs from the stonier part only in the greater freshness of its glass. The glass of the stony part always shows the beginnings of devitrification.

The other dykes of this type in the Great Cumbrae differ from the Eerie Port dyke only in minor details, such as the relative abundance of phenocrysts or the glassy base.

Mode.—An attempt was made to determine the quantitative relations of the minerals in the Eerie Port dyke by the Rosiwal method, but owing to the presence of glass, the fine grain, and the consequent uncertainty as to the exact boundaries of the minerals, the results must be regarded as only approximate. The anorthite phenocrysts were estimated from a number of hand-specimens. Table I shows the results of measurements for the "stony" (1) and "glassy" (2) parts of the Eerie Port dyke.

These figures show that this rock, if holocrystalline, would have been dofelsic. The glassy material contains little or no ferro-magnesian constituents, as shown later. As regards texture, the rock is megaphyric (large phenocrysts), hyalocrystalline (glass and crystals developed in approximately equal quantity), and perpatic (groundmass overwhelmingly predominant over phenocrysts).[1]

TABLE I.

	1.	2.
Anorthite ($Ab_1 An_9$) . .	7	10
Labradorite ($Ab_1 An_1$) . .	31	26
Pyroxenes	20	22
Glass	42	42
Specific gravity .	2·706	2·680

The composition of the glass may be calculated from the chemical analysis (Table II, 1) by deducting the mineral constituents in the proportions shown in Table I. After deducting 7 per cent of anorthite ($Ab_1 An_9$) and 31 per cent of labradorite ($Ab_1 An_1$), and assigning all the TiO_2 and Fe_2O_3 to ilmenite and magnetite respectively, the rest of the ferrous iron and lime with magnesia and the proper quota of silica form just 20 per cent of pyroxene, thus affording good evidence of the accuracy of both mineral and chemical analyses. All the mineral constituents have now been deducted; and as the ilmenite and magnetite may be held to represent the dark globulites in the glass, the remaining potash, soda, alumina, and silica must be present in the colourless glass, which must have the approximate composition SiO_2, 80·4; Al_2O_3, 9·9; Na_2O, 3·7; K_2O, 6·0. There is a small defect of Al_2O_3 as compared with the amount required to make orthoclase and albite molecules of all the potash and soda. It is possible, therefore, that there is a slight defect of Al_2O_3 in the analysis of the rock. From these results it may be concluded with fair probability that, apart from the dark globulites, there is no iron, magnesia, or lime in the glass, and that it consists entirely of orthoclase, albite, and free silica molecules.

CHEMICAL COMPOSITION.

The chemical composition of the Cumbrae dyke and of the similar dyke of Eskdalemuir, is set out in Table II, 1, 2. Compared with average andesite (II, 5) and average hypersthene-andesite (II, 6), they have the same amount of silica and alkalies, less alumina, but higher ferrous iron and lime. The Cumbrae types are therefore slightly more femic than the average andesites, but have a somewhat more sodic plagioclase felspar, as is well shown by the norms (Table III, 1, 2, 5, 6).

The comparison between the two cumbraites is hindered by the non-determination of TiO_2 in the Eskdale rock; but the smaller Al_2O_3 and lime, and the higher ferrous iron and magnesia, of the latter, cause a reversal of the relative proportions of diopside and hypersthene in the norms of the two rocks (Table III, 1, 2). The Eskdale rock is slightly more femic and less quartzose than the Cumbrae rock, as is shown by the dashes following the symbols for class and order in the former.

[1] Iddings, *Igneous Rocks*, vol. i, pp. 187, 199, 1909.

TABLE II.

	1	2	3	4	5	6
SiO_2	60·46	58·67	61·69	64·13	59·59	59·86
TiO_2	·68	n.d.	1·00	1·19	·77	·66
Al_2O_3	14·85	14·37	14·43	13·15	17·31	16·93
Fe_2O_3	1·14	1·64	1·23	1·08	3·33	2·86
FeO	5·82	6·94	5·86	6·31	3·13	3·56
MnO	·10	trace	·30	·27	·18	·22
MgO	1·46	4·65	2·81	1·08	2·75	3·25
CaO	8·19	7·39	4·97	3·62	5·80	6·36
Na_2O	3·27	3·01	3·20	3·64	3·58	3·35
K_2O	2·20	1·42	1·72	2·32	2·04	1·62
H_2O above 105° C.	1·42		2·36	2·71		
		2·02			1·26	1·08
H_2O at 105° C. .	·63		·25	·36		
P_2O_5	·05	—	·24	·31	·26	·21
BaO	—	—	·04	·09	—	·06
Cl	—	—	·02	—	—	—
	100·27	100·11	100·12	100·26	100·00	100·02

1. Cumbraite, Tertiary N.W. dyke (interior glassy facies), II, 4. 3. 4. (*tonalose*), Eerie Port, Great Cumbrae, Firth of Clyde. Anal. by Chetai Yu, B.Sc.; alkalies, TiO_2 and P_2O_5, by A. Scott, M.A., D.Sc.
2. "Pitchstone" (Cumbraite, Eskdale type), N.N.W. dyke with "sheath-and core" structure, II′, 4′. 3. 4. (*tonalose*), Eskdale, Dumfriesshire. Quoted from Sir A. Geikie, 1880, p. 253.
3. Leidleite (glassy part of sill showing "sheath-and-core" structure), II, 4. 3. 4. (*tonalose*), 2 miles S.S.W. of Pennyghael, Mull. Anal. E. G. Radley, Summ. Prog. Geol. Surv. for 1912 (1913), p. 69.
4. Inninmorite (inclined sheet, "contains small phenocrysts of basic plagioclase, and has acicular augite in the glassy base"), ′II, 4. 2 (3). 4. (*tonalose-dacose*), 1 mile S.S.W. of Pennyghael, Mull. Anal. E. G. Radley, Summ. Prog. Geol. Surv. for 1912 (1913), p. 69. For other analyses of leidleite and inninmorite see E. M. Anderson and E. G. Radley (1916, p. 212).
5. Average Andesite (Daly), ′II, 4. 3. 4. (*tonalose*). R. A. Daly, *Igneous Rocks and their Origin*, 1914, p. 26.
6. Average hypersthene-andesite, II, 4. 3′. 4. (*tonalose*). Calculated from 71 analyses of rocks described as hypersthene-andesite, hypersthene-augite-andesite, bronzite- and enstatite-porphyrite, enstatite-diabase-porphyry, and bronzite-tholeiite; taken from Iddings, *Igneous Rocks*, vol. ii, 1913; Iddings & Morley, paper on "Japanese Volcanic Rocks", Proc. Nat. Acad. Sci., Washington, vol. ii, 1916; Rosenbusch, *Gesteinslehre*, 3rd ed., 1910; Washington, Prof. Paper 14, U.S. Geol. Surv., 1903, etc.

Comparing the Cumbrae types with the related leidleite and inninmorite of Mull, it may be noted first that the latter are richer in combined water, and therefore in glass, than the Cumbrae types. Leidleite differs otherwise in containing a smaller percentage of lime, due probably to the absence of anorthite. This results in an almost exact reversal of the proportions of diopside and hypersthene in the norms of the two rocks (Table III, 1, 3), but otherwise the analyses and norms are very similar and give identical symbols in the American Quantitative Classification. The analysis of inninmorite shows much less lime and more silica, causing its norm to have a more quartzose and alkalic character than that of the Cumbrae type. This is reflected in the symbols for class and rang; and inninmorite falls into the subrang *dacose*, but close to the border between *dacose* and the neighbouring subrang *tonalose*, into which all the other analyses fall.

TABLE III.

	1	2	3	4	5	6
Quartz	14·04	11·28	19·14	22·32	15·48	15·54
Orthoclase	12·79	8·34	10·01	13·34	11·68	9·45
Albite	27·77	25·15	27·25	30·92	29·87	28·30
Anorthite	19·46	21·41	19·74	12·51	25·58	26·41
Diopside	17·79	12·71	3·00	3·13	1·33	3·59
Hypersthene	3·14	16·52	13·96	10·19	8·25	9·80
Magnetite	1·62	2·32	1·86	1·62	4·87	4·18
Ilmenite	1·37	—	1·98	2·28	1·52	1·37
Apatite	—	—	·51	·67	·67	·34
Class	II.	II′.	II.	′II.	′II.	II.
Order	4.	4′.	4.	4.	4.	4.
Rang	3.	3.	3.	2 (3).	3.	3′.
Subrang	4.	4.	4.	4.	4.	4.
	Tonalose	Tonalose	Tonalose	Tonalose-dacose	Tonalose	Tonalose

Interesting points arise from the consideration of the analyses of average andesite and average hypersthene-andesite. Comparing the two, average hypersthene-andesite has slightly more ferrous iron, magnesia, and lime, but less alkalies than the average andesite. Hence, the average hypersthene-andesite is slightly more femic and more calcic than average andesite, as is well shown by the norms and the magmatic symbols (Table III, 5, 6). Furthermore, both averages show about 15 per cent of normative quartz, and fall into the subrang *tonalose* (II, 4, 3, 4). Rocks with analyses like these should be regarded as dacites according to the classification adopted by Iddings.[1] They would belong to varieties of his *shastaite* (andesine-dacite),[2] transitional to *bandaite* (labradorite-dacite), devoid of modal quartz. Most of the analyses in this group fall into the subrang *tonalose*. The rocks called "andesite" by petrographers contain then, on an average, 15 per cent of normative quartz, which, however, rarely appears in the mode, and must exist occult in a fine-textured or glassy base. The term dacite should be restricted to andesitic rocks so rich in excess silica that it appears as quartz in the mode. The average dacite of Daly[3] has 25 per cent of normative

[1] *Igneous Rocks*, vol. ii, p. 106, 1913.
[2] Ibid., p. 111.
[3] *Igneous Rocks and their Origin*, 1914, p. 25.

quartz and falls into the subrang *lassenose* (I′, 4 (2). 3. 4, *yellowstonose-lassenose*). Furthermore, if the average hypersthene-andesite, based on seventy-one analyses, be compared with the average hypersthene-andesite computed by Daly on twenty analyses, it will be found that the differences are quite insignificant. This testifies to the distinctness and solidarity of this petrographic type, as distinguished by many petrographers on the basis of mineral composition. There can be little doubt but that a similar result would be arrived at for many other rock-types.

Relationships and Nomenclature of the Cumbrae Type.

It is very difficult to place this rock under the existing system of nomenclature. Similar rocks from the North of England and elsewhere have been called "augite-andesite", "basaltic andesite", "andesitic basalt", "andesitic dolerite", "tholeiite", "basalt", etc., a list which sufficiently indicates the petrographers' perplexity. The rock can be regarded neither as a true andesite nor a true basalt. In chemical composition it approaches the andesites; but if the term andesite be limited (as it should be if used specifically) to volcanic rocks with predominant andesine felspar, the Cumbrae rock clearly does not fall within this group. Its mineralogical expression, on the other hand, approaches that of a basalt; yet it cannot be placed thereunder because its chemical composition, with 60 per cent silica, is entirely unlike that of basalts. A similar difficulty of nomenclature has been experienced with the related dykes of Mull, and the Survey petrographers have solved the problem by giving the rocks new locality names, such as leidleite and inninmorite. The root of the difficulty is, of course, the abundant glass in the rock, which, as has been shown, must contain the excess silica and alkalies above that necessary to form the visible felspars. The probable mineral composition had the rock been holocrystalline is given approximately by the norm. There would have been about 47 per cent of a felspar near $Ab_3\,An_2$ (andesine), about 21 per cent pyroxenes, 12 per cent orthoclase, and 14 per cent quartz, i.e. the rock would have been a pyroxene-dacite; or, if the quartz had remained occult, as it appears to do in most andesites, a pyroxene-andesite.

Terms such as dolerite, basalt, andesite, dacite, and the like, have become far too comprehensive for a more discriminative petrography than frequently employed. If they are to be retained as more than mere field names, or comprehensive "omnibus" names, they should be frankly used as group or generic terms, comprising numerous sub-groups and species which should be given new names. Lacroix has recently begun the discrimination and renaming of ultrabasic forms of basalt and nepheline-basalt,[1] whilst Iddings has attempted to distinguish the numerous varieties of dacite, andesite, and basalt, according to their predominant felspar.[2]

If, however, nomenclature is based on mineral composition, there will always be a terminological difficulty with glassy rocks, for the greater the amount of glass the more abnormal will be the constitution

[1] A. Lacroix, *Comptes Rendus*, vol. clxiii, pp. 177–83, 213–19, 253–8, 1916.
[2] J. P. Iddings, *Igneous Rocks*, vol. ii, pp. 106, 191, 1913.

of the crystalline residuum as compared with the possible holocrystalline development. Glassy rocks are probably best named in such a way as to connect them with their nearest holocrystalline equivalents, and consequently, for accurate naming, the chemical composition will have to be determined in many cases. In general, however, petrographers will only find this necessary when the rock is of an abundant and widespread type not directly associated with its holocrystalline equivalent, as is the case, for example, with the rocks under discussion and the pitchstones of Arran.

The use of the dominant mineral constituents and texture as qualifying terms, and of the prefix *hyalo-*, in naming glassy rocks, results in some unwieldy designations, which may be illustrated as follows:—

Cumbraite = Anorthite-enstatite-augite-hyaloandesite.
Inninmorite = Anorthite-(uniaxial) augite-hyaloandesite.
Leidleite = Subvariolitic-augite-hyaloandesite.

In such cases the short locality-names, such as those given above, are much the more convenient for use when the rocks of a single petrographic province are being described, and for the Cumbrae rock I therefore propose the term *cumbraite*, which is defined according to the mineralogical and chemical composition given above. A new name should only be given to a glassy rock when it is an abundant, widespread, and homogeneous type, different either mineralogically or chemically from previously described glassy rocks, not when it is a mere hyaline facies of an associated holocrystalline rock. Whether these terms should obtain a circulation outside the discussion of the British Tertiary petrographic province is a question beyond the scope of this paper. My own opinion is that they should not, unless future work should show that they are widespread types in other petrographical periods and provinces.

Other Occurrences of Cumbraite.

Two dykes closely resembling the typical cumbraite occur on the Ayrshire mainland. One forms a N.W. dyke, 5 miles long, cutting across the River Ayr and its tributary the Coyle Water, near Sundrum House, about 6 miles east of Ayr. This rock is somewhat decomposed, but the anorthite phenocrysts remain fresh, and the enstatite is clearly recognizable by its pseudomorphs. The other occurrence is in the Burnock Water near Ochiltree, and appears to be quite a short dyke. In thin section this rock is seen to contain rather less glass than the typical cumbraite, and is richer in felspar and pyroxenes, especially the latter, thus providing a transition to the true tholeiites. The enstatite is pseudomorphed by a green fibrous mineral.

In the Cowal peninsula of Argyllshire a perfectly typical cumbraite occurs at Toward (Clough, 1897, pp. 131–2, 136).[1] This dyke is said to have a glossy band in the interior, running parallel with the length of the dyke, a feature connecting it with the Eerie Port dyke of the Cumbrae. A slightly different type which may, however,

[1] I am obliged to the Geological Survey for the loan of the Cowal slides on which these remarks are based, and also for the Eskdalemuir slides.

still be referred to cumbraite, occurs near Cruach Chuilceachan, in Cowal. This rock has been described by Sir J. J. H. Teall (in Clough, 1897, p. 155). It shows reticulations and bandings of varieties differing in texture and amount of glass. It carries glomero-porphyritic groups of basic felspar and hypersthene in a richly glassy groundmass containing microlitic felspar and augite.

The great Eskdalemuir (Dumfriesshire) dyke described by Sir A. Geikie (1880, pp. 219–55; 1897, vol. ii, pp. 133 et seqq.) forms a distinct variety of cumbraite distinguished texturally from the Cumbrae rocks. In the latter both the felspars and pyroxenes of the groundmass are slender and elongated, and may show a tendency to subvariolitic groupings, as also in the leidleite and inninmorite of Mull. In the Eskdalemuir type (Fig. 1*b*) the felspars are much broader, giving almost square or rhomboidal outlines, and the augite tends to form small clusters of minute, granular, equidimensional crystals. The enstatite stands out, however, as somewhat larger prismatic crystals. The abundant glass is yellow and comparatively free from microlites. Further differences are the comparative paucity of the large phenocrysts of anorthite, and the presence of sharply crystallized and uniformly distributed grains of magnetite in the Eskdalemuir type. Sir A. Geikie has noted the occurrence of curious enclosures of almost or quite holocrystalline material consisting mainly of granular augite and felspar laths. The "sheath-and-core" structure, of which this rock presents the type, must also be mentioned, as it appears, more or less perfectly, in many of the rocks treated in this paper. This rock may be distinguished as the Eskdalemuir type of cumbraite. The contrast between the textures of the two types is shown by Figs. 1*a* and 1*b* (see also Teall, 1888, pl. xiv, fig. 1).

Rocks probably belonging to the Eskdalemuir type occur in the four great W.N.W. dykes which traverse the Muirkirk district of Ayrshire, the most southerly of which is the continuation of the Eskdalemuir dyke. Enstatite, however, is not so abundant in these dykes as in those described above, and is always represented by green pseudomorphs. Furthermore, the anorthite phenocrysts are both small and sparse, and may be locally absent. The yellow glass of the groundmass provides abundant quartz on its devitrification.

At least two dykes in the Cowal area belong to the Eskdalemuir type and show the "sheath-and-core" structure, as described by Clough (1897, pp. 135, 142). The Cruach Mhor dyke carries a considerable amount of enstatite in small prisms. The dyke near Brackleymore School shows enstatite in central intergrowth with augite, but frequently decomposed to a fibrous green mineral of straight extinction. A dyke from the burn half a mile west of Loch na Leirg, Whiting Bay, Arran, possesses affinities with this type.

Typical cumbraites have not yet been found in Arran, but rocks which may represent an almost holocrystalline development of the cumbraite magma occur as north-west dykes penetrating the great sill of teschenite or crinanite at Dippin (Tyrrell, 1916, pp. 193–6). These rocks carry a few small phenocrysts of bytownite, frequently worn and corroded, with prisms of enstatite and augite, in a groundmass of labradorite laths, augite, and iron-ore granules. The base, which may represent a devitrified glass, now consists of an ill-defined, turbid, untwinned, felspathic substance and quartz, which carries numerous microlites of iron-ores. The rock is fully described in the above-cited paper. A N.N.W. dyke with similar characters occurs in the Church Burn at Corrie.

The dykes of the cumbraite facies, therefore, are distributed in a narrow band running S.S.E. from the Cowal peninsula, through the Great Cumbrae, down into central Ayrshire; and thence with a more south-easterly trend through the Muirkirk district towards the Scottish border. South of the border they give place to dykes which are regarded as basic varieties of inninmorite (Cleveland dyke) and the Brunton type of tholeiite (Anderson & Radley, 1916, p. 209). The cumbraites appear to belong to the regional or solitary dykes of Sir A. Geikie; and this may be the reason for their non-appearance in Arran, where the dykes are local and connected with the Arran centre of Tertiary eruption.

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

NOTICES OF MEMOIRS.

I.—The Oilfields of Egypt.[1]

BETWEEN the Sinai Mountains and the Red Sea Hills lies a depressed area bounded by faults and traversed by three hill-ranges, the Esh Mellaha, Zeit, and Araba Hills, which are separated from each other and from the main ranges by three plains and the Gulf of Suez. All these features trend approximately north-west and south-east. The breadth of the sunken tract is on the average 100 kilometres, of which the Gulf occupies about one-fourth.

Although petroleum has only been found in quantity in the peninsula of Jemsa, near the entrance to the Gulf, and at Rarquada[2] about 50 kilometres to the south-east of Jemsa, near the shore of the Red Sea, the whole of the area, together with a narrow strip on the shore of the Red Sea, extending as far as Ras Benas, is characterized by great geological similarity, and may be referred to as the oilfield region; but the district more especially dealt with in this report lies between 27° 10′ and 28° 10′ North lat., and 33° and 33° 50′ East long. A coloured geological map of this area and a plate of ten horizontal sections accompany the Report. During the progress of the work, extending over several years, the author examined some of the Roumanian oilfields under the guidance of Professor Mrazec, who subsequently visited Egypt and to whom we are mainly indebted for the horizontal sections.

Those portions of the Report which deal with the tectonic features of the oilfield region have recently been summarized by the author

[1] Report on the Oilfields Region of Egypt, by W. F. Hume, D.Sc., A.R.S.M., F.R.S.E., Director Geological Survey of Egypt. pp. viii and 103, with a geological map (1 : 150,000) from surveys by John Ball, Ph.D., D.Sc., F.G.S., 23 plates, and 9 text-figures. Cairo: Government Press, 1916. Price 30 P.T.

[2] Rarquada is opposite Gefatin Island

himself in the Geological Magazine,[1] so that it will be unnecessary in this notice to go into that branch of the subject in any detail.

In dealing with the succession of deposits the author follows the Lyellian method, beginning with the most recent. In this brief summary we will reverse the process, though we do not wish to suggest that this method should have been followed in the Report. The oldest rocks consist of granite and of ancient volcanic and sedimentary rocks, similar to those of the Red Sea Hills and the Sinai Mountains, probably of Archæan, certainly of pre-Carboniferous age. They form the cores of the asymmetric anticlines of the Esh Mellaha, Zeit, and Araba Hills as described by Dr. Hume in the paper already referred to. On the old floor formed of these rocks were deposited Nubian Sandstone, Cretaceous and Eocene strata. The succession is the same as that occurring on the western side of the Red Sea Hills and in Sinai, except that in the latter locality flat-bedded Carboniferous strata intervene between the old floor and the Nubian Sandstone.[2] The Cretaceous and Eocene rocks are seen only in the hill ranges where their thickness is often greatly reduced by folding. Their presence confirms the view generally held that these rocks were originally continuous over the whole area.

The Miocene rocks which follow rest on any of the underlying series. Thus on Shadwan Island they rest on granite and in the Zeit range on Lower Cretaceous strata. In the Esh Mellaha range, some 20 kilometres to the west of the Zeit range, both the uppermost Cretaceous and the Eocene rocks are present. It follows, therefore, that the Gulf of Suez marks the position of the axis of a post-Eocene and pre-Miocene anticline from which the sediment overlying the granite must have been wholly or partially removed by denudation before the Miocene rocks were deposited. We may remark in passing that in other parts of Egypt this interval is represented, to some extent at least, by the so-called petrified forests, the fluvio-marine series of the Fayum, and other deposits of a continental type.

Flint conglomerates and coral reefs occur at the base of the Miocene. In the Zeit range conglomerates, resting on Cretaceous strata, are immediately followed by a dark limestone containing fossils which M. Fourtau has identified with forms "typical of the Lower Miocene (Burdigalian) and of the Lower Helvetian (Lower Middle Miocene)". The limestone is succeeded by an important series of *Globigerina* marls with *Aturia aturi*, *Terebratula miocenica*, and a delicate Pecten fauna. Similar marls have been met with in a boring at Rarquada between 1,169 and 1,181 feet where they are underlaid by a limestone and a flint conglomerate, as in the Zeit range. This boring terminated in sands which Dr. Hume identifies with the Nubian Sandstone. The sands yielded oil. These fossiliferous strata are succeeded by deposits of clay, gypsum often calcareous, dolomitic limestones and salt; their total thickness cannot

[1] "Some Notes on the Post-Eocene and Post-Miocene Movements in the Oilfield Region of Egypt": Geol. Mag., January, 1917, pp. 5–9. The map illustrating this paper should be referred to.

[2] See review of Dr. Ball's memoir on *The Geography and Geology of West-Central Sinai*, Geol. Mag., February, 1917.

be less than 3,000 and may be as much as 6,000 feet. Above this great saliferous formation, which is generally unfossiliferous, occur oyster beds containing *Ostræa virleti* and an oyster of the *crassissima* type. Pending a more detailed examination of the palæontological evidence the beds from the flint-conglomerate up to and including the oyster beds are grouped together as being of Plio-Miocene age. They all belong to the Mediterranean area and can be connected up to the north with the Miocene deposits which occur between Suez and Cairo.

The oyster-beds are followed by strata containing the remains of sea-urchins and Pectens now living in the Red Sea and Indian Ocean, together with some forms which are apparently extinct. These deposits are referred to as Plio-Pleistocene. They mark the invasion of what had hitherto been a southward extension of the Mediterranean province by Erythræan forms of life. The plains are largely covered by thick deposits of gravel, derived from the waste of the hills. These are classed as recent, together with a raised beach of corals and molluscs now living in the Red Sea. The beach forms a marked feature on the Zeit and Jemsa coast at an average height of 15 metres.

Let us now consider the great saliferous formation, with which the oil appears to be associated, in greater detail. Gypsum is the most prominent rock at the surface. Salt in thick beds is only known from the borings. The gypsum is interbedded with clays or marls, and in some places, as in the Jemsa peninsula, with dolomitic limestone. Vertical sections of four borings are given. They show remarkable changes within short distances. Bore 11 passed through alternations of gypsum and clays to a depth of about 500 feet; then through thick beds of salt, separated by thin beds of clay, limestone, and gypsum, to a depth of 2,650 feet, where it ended in salt. The total thickness of salt in this section was found to be about 1,900 feet, or 600 metres. Bore 1, which was apparently situated about one kilometre from Bore 11, is represented as being entirely in limestone. It reached a depth of 1,300 feet. The other two bores, less than 300 metres from Bore 1, were in gypsum, with thin beds of clay and limestone. Speaking of the Jemsa oilfield, Dr. Hume says: "Sections have been made of the area so as to include the bore-profiles, but efforts to explain the present conditions either as simple anticlines or synclines have ended in complete failure. There is a provoking horizontality in the strata of the eastern hill of Jemsa, immediately above the oil-belt on the east coast. . . . What we do know is that the Jemsa borings which have yielded profitable oil occupy a long thin band close to the sea, parallel to the general fold movement of the country."

The oil at Jemsa appears to have been obtained from the dolomitic limestone which is porous, and therefore likely to form a good reservoir rock. Fragments of a similar limestone are common on the surface of the gypsum throughout the oilfield region. Dr. Hume suggests that this feature, and also the great thickness of limestone met with in some of the borings, may be due to the removal of gypsum in solution from beds containing both carbonate and sulphate of lime. Mr. Lucas contributes a chapter on the solubilities of these two substances in water and saline solutions, in which he shows that the relative solubility of gypsum increases up to a certain point as the salinity increases; and Dr. Hume points out that the underground waters at Jemsa have approximately the composition most favourable for the solution of gypsum. There appears to be strong reason for believing that the circulation of water in the saliferous formation has brought about great changes in the nature and distribution of the original materials.

Salt which has been met with in several bores does not occur in one central core as in the Roumanian fields, but is interstratified with shales and gypsum. It is best developed in the minor anticlines, and "Professor Mrazec was strongly impressed with the idea that these strata [the salt-beds] were derived by a leading action from salty clays, similar to those well developed at the surface, whereas beds of salt have never been noted on the large scale in the above ground observations". Dr. Hume suggests that the saliferous deposits were formed in a slowly sinking area into which sea-water could gain access, that the evaporation over this area was sufficient to cause the precipitation of gypsum and salt, and that while this was going on streams were bringing down clay and calcareous matter from the surrounding land.

The similarity in many respects of this formation to that of the Roumanian oilfields is referred to. May we not extend the correlation? *Aturia aturi* is a characteristic fossil of the "Schlier" which, according to Suess[1] and others, includes the Carpathian salt-beds, and probably also those of Armenia and Azerbigan, of the Iranian tableland as far as Khorasan, of the valley of the Tigris, and of the coast of the Persian Gulf. Doubt may exist as to the precise correlation of all these saliferous formations which, as Suess says, "afford us the spectacle of a great expiring sea"; but it seems clear that, both as regards age and mode of formation, the deposits of the Egyptian oilfield are closely allied to them; and it is with them that some of the most important oilfields of the world are intimately associated.

No definite opinion is expressed as to the origin of the petroleum, but the porous limestone (Jemsa) and the Nubian Sandstone (Rarquada) are regarded as reservoir rocks. Indications of oil are most conspicuous on both sides of the Gulf of Suez, and as the overfolding of the anticlines is directed towards the Gulf, it is suggested that the post-Miocene stresses probably reached their greatest intensity in this region, and may therefore have forced the oil into any rocks in the neighbourhood capable of containing it.

No detailed records of bores are given, except the four at Jemsa, and no statistics of production. It is to be regretted that so much secrecy should be considered necessary by those engaged in controlling and developing the economical resources of a country, and very doubtful whether it is not carried much further than is required for commercial purposes. Rivals generally find out sufficient for their purpose, and the progress of science is, therefore, often unnecessarily

[1] *Face of the Earth*, vol. i, p. 309, English translation.

retarded. Moreover, valuable information may be, and often is, lost. Wherever Governments grant facilities for exploration by deep bores they should see that accurate records are kept and made public after a reasonable lapse of time.

The two outstanding features which sharply differentiate the oil-field region from the plateau regions of Sinai and Egypt are the presence (1) of a thick series of Miocene rocks belonging to the Mediterranean area, and (2) of sharp folding due to tangential pressure. We repeat the question that we put in reviewing Dr. Ball's memoir on West Central Sinai. Did the Miocene sea advance over a planed down surface of the older rocks? It was at one time supposed that some at least of the faulting in the region between Suez and Cairo was of post-Eocene and pre-Miocene date, and that Miocene rocks had been deposited against "horsts" of Eocene limestone. That view was disproved by Barron,[1] who showed that they were superposed upon, not apposed against, the Eocene strata, and that no evidence of pre-Miocene faulting was to be found in that district. Now Dr. Hume comes forward with evidence that the Miocene rocks of the oilfield region were formed over the denuded arch of the great post-Eocene fold whose axis coincided approximately with what is now the Gulf of Suez. Although we are not able to define with precision the boundaries of this southward extension of the Miocene sea there is some evidence to show that it did not extend far beyond the faults which bound the sunken tract on the east and on the west, and, therefore, as Dr. Hume points out, that it found a gulf agreeing approximately in position and direction with this tract and its continuation in the Red Sea trough. But in any case there must have been a considerable geocratic movement in post-Miocene times, for Dr. Ball has shown that Miocene rocks occur at a height of 642 metres on Sarbut el Gamal[2] in West Central Sinai, and has estimated the throw of the post-Miocene faults in that region at about 2,000 metres. Even allowing for the possibility that this may be an over-estimate, there seems no escape from the conclusion that the oilfield region owes its position largely to subsidence along faults of later date than the Miocene rocks of the district. But we must await the more precise determination of the palæontological horizons before attempting to correlate the physical history of the oilfield region with that of the Mediterranean area to which it belonged until it was invaded by the Erythræan fauna in comparatively recent times.

It is interesting to compare the views of Suess as to the structure of the district with those set forth in this memoir and in other publications of the Egyptian Geological Survey. In his chapter on the Great Desert Plateau Suess shows that flat-bedding in the Cretaceous and Tertiary rocks is the characteristic feature of large portions of North Africa south of the Atlas range, of the Sinai peninsula, of North and South Arabia, of Palestine and Syria, and that the same feature probably extends as far east as the Persian

[1] *The Topography and Geology of the District between Cairo and Suez*, Cairo, 1907, p. 55.

[2] See GEOL. MAG., February, 1917, p. 83.

Gulf. The only post-Tertiary movements that he recognizes over this vast area, extending eastwards from the Atlantic Ocean for some 3,000 miles, are "in the form of subsidence, particularly as great trough-subsidences, which are here and there associated with flexure of the edges. On the other hand, tangential movement and folding are entirely absent, at least as far as we can judge at present". This view can no longer be maintained if we are to understand by "subsidence" movements along normal faults. Flat-bedding, so far as the eye can judge, certainly is the dominant feature in the Egyptian portion of the Nile Valley, in the Oases, and in Sinai. But, as Dr. Hume has pointed out,[1] the V-shaped outcrops on the geological map of Egypt require the assumption of a broad syncline whose axis dips slightly to the north, while the relations of the Cretaceous and Eocene rocks to the Red Sea Hills and Sinai Mountains indicate the presence of a complementary anticline to the east. Thus folds of great amplitude certainly occur in this portion of the desert plateau, reminding one of the swell of the ocean which is often felt far away from the storm centre which produces it. Now Dr. Hume shows us that sharp folding due to tangential pressure is also present. But this alone would probably not have led Suess to modify his general view. He would doubtless have regarded it as connected with a trough subsidence and therefore of only local importance.

The Report is well illustrated by photographs of scenery and figures of the more characteristic fossils which are briefly described by M. Fourtau in a special chapter. It does not profess to be final. The map is said to be provisional and research is still going on. We await with interest the communications which are to follow, and conclude by wishing success to those who are engaged in developing the Egyptian oilfield, to whom we are indebted, both directly and indirectly, for so much geological information about this most interesting region.

J. J. H. T.

II.—The Conchological Features of the Lenham Sandstones of Kent, and their Stratigraphical Importance. By R. Bullen Newton, F.G.S., of the British Museum (Natural History).

Part II.

Conclusions.

We gather from the previous literature on this subject that the majority of investigators have agreed that the Lenham Beds are equivalent to the Diestian deposits of Belgium, which have been generally recognized by geologists as belonging to the base of the Pliocene system, on account of the shell remains exhibiting a marked Miocene facies with many species identical or related to southern or Mediterranean forms. The Miocene aspect of the Lenham fauna is very pronounced, as out of the seventy-seven conchological species that have been determined in the present work, forty-seven, or sixty per cent, date their origin from the Vindobonian

[1] Explanatory notes to accompany the geological map of Egypt.

(Helvetian–Tortonian) stage, which represents the middle part of that epoch in such countries as Germany, Italy, France (S.), Holland, Denmark, and Austria (Vienna Basin). Again, twenty-six of the Lenham species occur as well in the Redonian beds of Gourbesville, Normandy, which are either of Vindobonian or Messinian age, and therefore Miocene. These Gourbesville deposits are of peculiar interest. They were originally discovered by Vasseur,[1] and ascribed to Pliocene or Red Crag times, having been more critically studied since by M. G. F. Dollfus,[2] who in 1880 regarded them as of similar age, although subsequently determining them as belonging to his[3] "Etage, Rédonien", which in explanation was stated to be neither Helvetian nor Plaisancian, but equivalent in time to the Tortonian stage of the Miocene, notwithstanding that he had previously paralleled this new horizon with the Anversian Beds of Belgium.[4] The Redonian fauna was considered to be related to the Gedgravian (Coralline Crag) of England.

About twenty of the Lenham shells, including *Anadara diluvii*, occur in the Upper and Middle Miocene of Holland, and a rather smaller number of species in the same horizons of Denmark, as determined by Molengraaff and Van Waterschoot Van der Gracht[5] for Holland and by Ravn[6] for Denmark. The Pelecypod, *Anadara diluvii*, is of frequent occurrence in the Lenham Beds, and although unknown in the Diestian of Belgium, it is found in the Bolderian (= Tortonian) and Anversian (= Messinian) of that country, as well as in the Vindobonian of Germany, France, Austria, and Italy, and in the Plaisancian deposits of Italy and France; its only British occurrence from the Lenham sandstones was first recorded by Mr. Reid. The Lenham fauna presents an interesting resemblance to that of the Upper Miocene of North Germany (Reinbeck and Holstein), described by Zimmermann[7] and Gottsche,[8] and regarded as Messinian or the latest stage of the Miocene period, a formation-term introduced by Mayer-Eymar,[9] to include Pontian–Sarmatian, Zanclean, and Miocene of other authors. The North German Miocene deposits contain twenty-five species of Mollusca which are also found in the Lenham Beds, among them being *Streptochetus sexcostatus*, *Zaria subangulata*, *Tellina benedeni*, *Papillicardium papillosum*, etc.

Speaking further of this Miocene facies of the fauna, it may be observed that *Drillia obeliscus* and *Clavatula jouanneti* are first known in Burdigalian times, whereas *Margaritifera phalænacea* commenced its career in the Aquitanian stage, which forms the basal or oldest

[1] Bull. Soc. Géol. France, ser. III, vol. vii, p. 741, 1879.
[2] Bull. Soc. Géol. Normandie, 1880.
[3] Assoc. Française-Cherbourg, 1905, published 1906, pp. 358–70.
[4] Bull. Soc. Géol. France, ser. IV, vol. iii, p. 258, 1903.
[5] "Niederlande": Handb. Region. Geol., vol. i, pt. iii, p. 53, 1913.
[6] "Molluskfaunaen I Jyllands Tertiaeraflejringer, etc.": Mus. Min. Géol. Univ. Copenhague: Paléontologiques, No. 7, 1907 (plates and text).
[7] "Ueber der Schichten der Tertiärformation welche bei Reinbeck durch die Hamburg, etc.": Amtl. Ber. Deutsch. Nat. Aerz. Kiel (1846), 1847, pp. 232–4.
[8] Die Mollusken-Fauna des Holsteiner Gesteins": Abhandl. Geb. Nat. Ver. Hamburg, vol. x, No. 8, pp. 14, 1887.
[9] *Cat. Syst. Foss. Tert. Mus. Zurich*, 1867, pt. ii, p. 13.

division of the Miocene formation. The following Gastropods may also be referred to as dating from the Vindobonian stage of the Miocene; *Streptochetus sexcostatus*, also Messinian and Anversian; *Bonellitia serrata*, ranging into the Italian Plaisancian; *Terebra acuminata*, occurring also in the Messinian of North Germany, the Anversian of Belgium, and in the Plaisancian and Astian beds of Italy; *Maculopeplum lamberti*, recorded as well from the Redonian of France, the Diestian and Scaldisian of Belgium, the Box-stones and the Coralline and Red Crags of England; and *Ficus reticulata* known also from the Redonian of France, the Messinian of North Germany, the Bolderian, Anversian, and Diestian of Belgium, Box-stones, Lenham Beds, and Coralline Crag of Britain, Plaisancian and Astian of France and Italy, and belonging also to recent seas. Among the chief Pelecypods similarly originating in Vindobonian times are: *Glans senilis*, known also in the Redonian, Scaldisian, and Coralline Crag; *Arcopagia ventricosa*, also Plaisancian and Astian; *Tellina benedeni*, Messinian and from Bolderian to Scaldisian; *Plagiocardium hirsutum*, Plaisancian and Astian; *Astarte basteroti*, Redonian, Diestian, and Scaldisian; *Papillicardium papillosum*, Messinian, Redonian, St. Erth Beds, Plaisancian and Astian to recent seas; *Cyprina rustica*, Messinian, Anversian to Scaldisian, Box-stones, and Coralline Crag; *Cyrtodaria angusta*, Messinian, Bolderian to Scaldisian, Box-stones, and Coralline Crag; and *Panopæa menardi*, Anversian, Messinian, Box-stones, Coralline and Red Crags.

The only representative of the Brachiopod group of shells is *Terebratula perforata*, which ranges through the Redonian of France, Bolderian to Scaldisian of Belgium, and the Coralline and Red Crags of Britain. With the exception of *Ficus reticulata* and *Papillicardium papillosum*, which exist in present seas, the species thus enumerated are extinct. Several of the Lenham species occur in the Bolderian and Anversian beds of Belgium, the latter according to M. Dollfus[1] being Vindobonian, and equivalent to his Redonian stage, although attributed by Renevier[2] to the later Pontian (= Messinian) division of the Miocene. The Anversian and Diestian occurrences represent 34 and 30 species respectively, Box-stones 12, St. Erth 15, and the Coralline Crag 50. It has been urged by Mr. Harmer that the Coralline Crag fauna is younger than that occurring in the Lenham deposits because several of the older shells found there and that have been previously alluded to are absent in the Coralline Crag beds, a fact more or less accurate, although some important forms do occur in those deposits, such, for instance, as *Margaritifera phalænacea*, *Glans senilis*, *Cyrtodaria angusta*, *Panopæa menardi*, *Terebratula perforata*, etc.

All these facts seem to suggest that the Lenham and Coralline Crag faunas, although showing certain differences of detail, are, nevertheless, to be regarded as presenting a close relationship, and therefore to be considered as of approximately the same age. Marked affinities are also noticeable in the molluscan faunas of the Coralline

[1] Bull. Soc. Géol. France, ser. IV, vol. iii, pp. 256–60, 1903.

[2] "Chronographie Géol.—Text Explicatif": Comp. Rend. Cong. Géol. Internat. (1894), 1897, p. 597.

Crag and the Diestian beds of Belgium. This is apparent from Mr. Harmer's list of the Diestian species (Quart. Journ. Geol. Soc., 1898, vol. liv, p. 317), in which, out of rather more than seventy forms enumerated, nearly all are stated to occur in the Coralline Crag.

A considerable proportion of the Anversian species of Belgium, as listed by M. Van den Broeck (Ann. Soc. Mal. Belgique, 1874, vol. ix, pp. 118–121), likewise occur in the Coralline Crag, as out of a list of 175 species 80 are recognized as being found in that formation.

The following table shows the numerical representation of the seventy-seven Lenham species occurring in the principal formations :—

Recent	40	species.
Post-Pliocene	23	,,
Astian	36	,,
Plaisancian	40	,,
Scaldisian	44	,,
Norwich Crag	12	,,
Red Crag	48	,,
(probably derived from Coralline Crag).		
Coralline Crag	51	,,
St. Erth	16	,,
Box-stones	13	,,
Diestian	30	,,
Anversian	34	,,
Messinian	25	,,
Bolderian	17	,,
Redonian (Tortonian)	26	,,
Vindobonian (Helvetian–Tortonian)	47	,,

The so-called Older Pliocene beds of Mr. Reid's memoir are characterized by shells with a southern facies indicating warmer climatic conditions than prevailed in the Red Crag period, when boreal and Arctic species were largely predominant. The East Anglian Box-stone deposits have been regarded by Mr. Harmer[1] as the probable equivalent in time of the Waenrode Beds of Belgium, which Van den Broeck[2] has considered to be of Bolderian age and therefore Miocene. In this connexion it is interesting to note that the Box-stone beds have been quite recently regarded as Miocene by Mr. Reid.[3]

Sir Ray Lankester[4] determined some Proboscidean remains from those beds as a new species of *Mastodon*, although subsequently recognizing them as a variety of *M. angustidens* of Cuvier,[5] being further of opinion that they were older than the Diestian of Belgium. It is well known that Cuvier's species characterizes the older Vindobonian beds of France, and is frequently found in the ossiferous deposits of Sansan. When the Box-stone Mollusca are more studied, such an age as is here indicated will probably be more conclusively proved; in the meantime the evidence is in favour of those deposits being older than the Lenham Sandstones. The St. Erth deposits of Cornwall were originally described by Searles Wood[6] as

[1] Quart. Journ. Geol. Soc., vol. lvi, p. 708, 1900.
[2] Ann. Soc. R. Mal. Belgique, vol. xix, pp. lvi–lxvi, 1884.
[3] Mededeel. Rijks. Delfst., 1915, No. 6, p. 9.
[4] Quart. Journ. Geol. Soc., vol. xxvi, pp. 507–9, 1870.
[5] Geol. Mag., 1899, p. 292.
[6] Quart. Journ. Geol. Soc., vol. xli, pp. 65–73, 1885.

of Red Crag age, although he observed that "the character of the mollusca, as a whole, is essentially southern, no peculiarly Arctic shell having as yet occurred".

The fauna was more particularly described by Professor Kendall and R. G. Bell[1] in the following year and again referred to as contemporary with that of the Red Crag, a result contrary to the views of Mr. Reid, who claimed a greater age. Since that discussion Mr. Alfred Bell[2] has published a paper on the St. Erth Mollusca and regarded their age as Mio-Pliocene or Messinian, a somewhat similar horizon having already been partially suggested by Gwyn Jeffreys,[3] who stated: "He was not clear whether the St. Erth deposit was of Older Pliocene or possibly of Upper Miocene age." In the same paper Mr. A. Bell placed upon record an important opinion he had received from M. Dollfus, which reads as follows: "You have in St. Erth exactly the same Pliocene fauna as we have at Gourbesville in the Cotentin," a statement more or less confirming the previous researches of Mr. Reid (1890), who had acknowledged the necessity of a strict comparison between the molluscan species of Gourbesville and those of the St. Erth deposits, as the fossils from the former locality "point to conditions very similar to those indicated by the shells from St. Erth". The Gourbesville fauna, however, as previously mentioned, is now considered to be of Miocene age (Tortonian or Messinian). About fifty per cent of the Lenham shells are extinct species, a somewhat similar percentage marks the Boxstone fauna (according to a calculation made from Mr. A. Bell's memoir in Journ. Ipswich Field Club, vol. iii, pp. 7, 8, 1911), and Mr. Reid (Survey Memoir, 1900, p. 64) has stated that the Coralline Crag and St. Erth deposits contain each about forty per cent of extinct shells. It will be observed that there is a similarity running through these percentages of extinct forms, which appears to furnish satisfactory evidence for regarding the four stages of Mr. Reid's "Older Pliocene" group as of the same approximate geological age, although the Box-stones, as before explained, may be somewhat older.

From the foregoing details of the different faunas involved in this discussion, it is certain that many of the species had their origin in Miocene times. There is good reason for recognizing the St. Erth shells as of Miocene age, because of their relationship to species characterizing the French Redonian. Similarly, the Box-stone fossils would belong to the same period, as their affinities are with those of the Bolderian of Belgium, which is generally regarded as Tortonian or Upper Vindobonian.

Lastly, the Lenham fauna with its strong Vindobonian and Coralline Crag facies should also be placed in the Miocene, and in consideration of its relationship to that characterizing the Upper Miocene deposits of Northern Germany and the Anversian beds of Belgium, I would recognize it as belonging to the latest or Messinian stage of the Miocene, which is synonymous with the term Mio-Pliocene. The stratigraphical name of Mio-Pliocene was introduced into Belgian

[1] Quart. Journ. Geol. Soc., vol. xlii, pp. 201–14, 1886.
[2] Trans. Roy. Geol. Soc. Cornwall, vol. xii, p. 133, 1898.
[3] Quart. Journ. Geol. Soc., vol. xli, p. 72, 1885.

geology by Mourlon,[1] who regarded it as including Lyell's "Upper Miocene" and Dumont's "Pliocène Diestien". It was recognized as comprising two divisions or zones, the first characterized by *Panopæa menardi*, and the second by *Glycymeris* [*Pectunculus*] *pilosa*, both of which are now included in the Anversian stage, or "Crag Noir", of the Belgian Miocene, which is developed at Edeghem and Antwerp. These two Pelecypods occur in the Vindobonian strata of Europe, *P. menardi* being found as well in the Lenham Beds, Box-stones, and Coralline Crag beds, whereas *Glycymeris pilosa* is found present in the same horizons, being likewise a member of the St. Erth fauna. Although acknowledging certain differences in the faunas of these Upper Tertiary horizons, which may be probably accounted for by different conditions of environment, no great disparity of time need be allowed for in considering their geological age. I am induced, therefore, from a knowledge of their conchology, to regard the Coralline Crag,[2] the St. Erth Beds, and the Lenham Beds of Britain, together with the Diestian and the Anversian of Belgium, as of Upper Miocene age, and belonging to the stage Messinian or Mio-Pliocene, while the Box-stones, or Nodule beds of East Anglia, I should consider as referable to the Vindobonian division of the Middle Miocene.

In accordance with these views, therefore, the following synopsis of the various geological horizons referred to is now proposed:—

Recent		British and Mediterranean Seas.
Post-Pliocene	Glacial, etc.	
Pliocene	Norwich Crag	
	Red Crag (= Astian of Italy and Scaldisian of Belgium)	Britain.
Upper Miocene or Messinian (= Pontian or Mio-Pliocene)	Coralline Crag	
	Diestian	Belgium.
	St. Erth Beds (Cornwall)	Britain.
	Lenham Sandstones	
	Anversian (= "Crag Noir" of Edeghem and Antwerp)	Belgium.
	Upper Miocene	Germany (N.).
Middle Miocene (=Vindobonian)	Redonian (=Tortonian or Anversian)	France (N.W.).
	Box-stones (=Bolderian of Belgium)	Britain.
	Helvetian–Tortonian	Italy, Vienna Basin, Holland, Denmark, etc.
Lower Miocene	Burdigalian	France (S.W.).
	Aquitanian	Italy.

[1] *Géologie de la Belgique*, vol. i, p. 261, 1880.

[2] The foraminiferal evidence, also, lends support to the view that the Coralline Crag is of older age than has yet been accepted. According to the Monograph on the Crag Foraminifera by Jones, Burrows, and others (Palæontographical Society, 1897, p. 369) the following species are recorded from the Coralline Crag of Sudbourne: *Nummulina planulata*, *Amphistegina vulgaris*, *Operculina complanata*, and *Orbitoides aspera*, formerly determined as *O. faujasi*. These are said to be "derived from earlier beds", although from a recent examination of the specimens, which are in the Geological Department of the British Museum, they present the appearance of having been found in situ. However, the so-called *Nummulina* might indicate an Eocene or Oligocene horizon, but the other organisms are characteristically Miocene, especially when it may be stated that in *Orbitoides aspera*, after

Lastly, I may mention that in 1907 I was favoured with a visit from the late Professor Dr. Gottsche, Director of the Hamburg Museum, and one of the chief authorities on the molluscan fauna of the North German Miocene deposits, for the purpose of examining the Lenham Collection of the Museum of Practical Geology, which was then in my keeping at the British Museum; he was specially interested in some specimens referred to in Mr. Reid's memoir as an elongated variety of *Triton heptagonum* (?), being confident that they represented Beyrich's *Fusus sexcostatus*, a characteristic fossil of the Upper Miocene formation of North Germany. He was further of opinion that the Lenham Beds were older than had hitherto been supposed, and he considered that they should be referred to the Miocene period.

REVIEWS.

1.—Some Problems in South African Geology. By P. A. Wagner. Proc. Geol. Soc. South Africa, 1917, pp. xix–xxxix.

In his Presidential Address to the Geological Society of South Africa for 1917 Mr. P. A. Wagner dealt at some length with four outstanding problems of the geology of that country, namely, the origin of the gold-reefs of the Rand, the genesis of the diamond, alteration of diamonds after their formation, and the nature of the famous salt pan near Pretoria. On each of these he had something of interest to say. An excellent summary is given of recent views as to the source of the gold in the Banket. Dr. Mellor has recently brought forward evidence in favour of the "placer" theory, founded largely on the actual distribution of the gold in the conglomerates. It is found by assays that the gold is richest where the pebbles are largest, and it is therefore argued that the gold was deposited by the strong currents that brought the large pebbles, the weaker currents that could bring only the finer sand not being competent to carry the heavier grains of gold. Nevertheless, the actual character of the particles of gold indicates recrystallization in place. Mr. Wagner dissents from Dr. Mellor's view that the quartzites and conglomerates were deltaic deposits and regards them as having been formed on beaches in a subsiding area.

The author considers kimberlite as the hypabyssal or volcanic form of a peridotite magma which he believes to underlie the granitic and other rocks at a great depth, and he regards the diamonds as original constituents of this magma, brought up, often in a fragmental form, during extrusion. He also gives some facts of great interest as to the possible effect of radio-activity or other agencies on diamonds after they reached their present position. This subject, however, appears to be of a very speculative nature, and much work is obviously required.

The salt pan on the farm Zoutpan, 25 miles N.N.W. of Pretoria, now gives rise to a considerable industry. The pan itself is a most

careful rubbing down of the horizontal surface on the median plane of the figured example, there is exposed a series of minute chamberlets of squarish or hexagonal outline which can only belong to the Miocene genus *Lepidocyclina*.

remarkable structure, and has been described by Cohen, Kynaston, and Hatch & Corstorphine. It presents the appearance of a crater lake, dry in winter, but until disturbed by working it contained a brown brine in the rainy season. It is surrounded by a rim of granite some 200 feet high, with a gentle slope on the outside and a steep slope on the inside. The rim of granite is a most remarkable feature. The floor of the pan has been pierced by borings to a depth of 1,100 feet, and it is found to be composed of alternate layers of salt and mud. The salts have on the average very nearly the theoretical composition of trona, $Na_2CO_3 . NaHCO_3 . 2H_2O$, with some sodium chloride but very little sulphate. The evidence as to the origin of these salt deposits is scanty and not very satisfactory; they may be derived from the decomposition of the perthitic felspar of the granite or from underground waters of either volcanic or meteoric origin. Opinions differ as to the origin of the pan itself. It may be due to the impact of a large meteorite, like Coon Butte in Arizona, or it may be a volcanic pipe like the Maare of the Eifel or Geitsi Gubib in South-West Africa; the latter appears the more probable, although the upward bulging of solid granite in the form of a dome or even of a ring seems rather difficult of belief. It is evident that the last word has not yet been said on the origin of structures of this and related types.

R. H. Rastall.

II.—Analyses of Western Australian Rocks, Meteorites, and Natural Waters. By Edward S. Simpson, B.E., B.Sc., F.C.S. Bull. No. 67, Western Australia Geological Survey.

This bulletin is a collection of the records of all the analyses performed in the Government laboratory between the years 1897 and 1916. It deals with rocks, meteorites, and natural waters.

The rocks are divided into igneous, metamorphic, and sedimentary, and these divisions are subdivided according to silica percentage to facilitate reference to the lists. The compiler states that these analyses are not to be taken as a quantitative representation of the rock-types of Western Australia, but that they deal, as is natural, with the types of greater interest to the miner and the agriculturist. In addition to the analyses of the igneous rocks, Brögger–Hobbs diagrams are given of many types, and in most cases the "mode" and "norm" are given, and the rock is classified according to the quantitative system.

Most of the rocks fall into the described groups, but two of them, an amphibolite and a gabbro, fall inside no known group, and have a sufficiently definite composition to warrant placing them in a new group (IV, i, i, 3, 2), for which the name Murchisonose is proposed.

In the analyses of the sedimentary rocks two points of interest present themselves. The first is the composition of the dune sands from Dongara, which consist principally of foraminifera, calcareous algæ, and powdered mollusca, and have at times as little as 3·8 per cent of silica, being almost entirely made up of calcareous matter. The other point of interest is the excessive humidity of the bituminous coals, which often contain as much as 23 per cent of moisture. Among the rocks there is a curious series of dyke or vein rocks of unknown origin called "hæmatite quartz rocks", which are placed in a class by themselves. They consist principally of hæmatite and chalcedony, and have an iron content of 47 to 54 per cent of Fe_2O_3, which occasionally rises as high as 92 per cent in the hæmatite rocks. In the section on meteorites twelve undoubted siderites of nickeliferous iron are described, the large numbers of doubtful obsidianites which have been found in the colony being neglected. The natural waters analysed are drawn from a variety of sources—artesian wells, surface wells, and mines. They are used for drinking water, steam-raising, irrigation, stamp batteries, and the cyanide process. The amount of solid matter is often very high, sometimes reaching more than 15 per cent, which is principally sodium chloride. It is interesting to note that in the surface waters of one district there is a considerable quantity of sodium nitrate, amounting to 19 parts of nitrogen to the million. This is attributed to a train of favourable circumstances, there being great bacterial activity in the soil, low rainfall, and a dominant vegetation of a leguminous plant called "mulga".

W. H. Wilcockson.

III.—British and Foreign Marbles and other Ornamental Stones. By John Watson. Cambridge University Press, 1916. 5*s.* net.

THIS descriptive catalogue is a companion volume to the same author's well-known *Building Stones*, and it shows the same scholarship and regard for accuracy that characterized the earlier catalogue. The rocks described include (besides marbles) onyx marbles, malachite, alabaster, serpentine, and jade, as well as other less common ornamental stones. The work will appeal very strongly to the architect, and to the geologist who is interested in the application of rocks to decorative purposes.

IV.—The Etchegoin Pliocene of Middle California. By Jorgen O. Nomland. University of California Publications, Bulletin of the Department of Geology, vol. x, No. 14, pp. 191–254, pls. vi–xii, 2 text-figures. Issued April 19, 1917.

THIS memoir treats very exhaustively of the Etchegoin group of rocks and its fauna as developed in the Coalinga District of Middle California, which is considered to be of Pliocene age, although mapped as Upper Miocene by Ralph Arnold and F. M. Anderson. The author regards the vertebrate evidence as confirmation of this horizon, Professor J. C. Merriam having recently described from these beds such genera as *Pliohippus*, *Neohipparion*, *Mastodon*, etc. Faunal lists are drawn up of the marine invertebrates showing a strong resemblance to those of the Jacalitos formation, which, although hitherto kept distinct, may now, in the author's opinion, be united to the Etchegoin group. The memoir terminates with descriptions of several new species of Mollusca—seven Pelecypoda and 8 Gasteropoda—and a doubtful *Serpula*, all of which are suitably figured.

V.—Report of the Rugby School Natural History Society for the Year 1916. 1917.

GEOLOGY still maintains an excellent position among the various sections of this Society. In the present Report (pp. 98–100) it is noted that visits were made to Napton Quarry, and that fossils were collected from the *Capricornus* zone of the Lower Lias. Some pits at Nuneaton are also referred to as having yielded Carboniferous ferns and *Calamites*, while marlstone fossils were obtained from Fawsley Park, near Badby. Doubtless the better part of such material will find its way into the School Museum, which already contains good palæontological specimens, those of local interest being perhaps of greatest importance. This Report also informs us that the Rugby School Natural History Society has now been in existence for fifty years, a fact on which we venture to offer our congratulations.

VI.—New Tertiary Insects. By T. W. A. Cockerell. Proc. United States National Museum, vol. lii, pp. 373–84, pl. xxxi, 1917.

THE material described in this paper was obtained from the Eocene (Oil Shales) of Western Colorado, from the Miocene beds of Florissant, Colorado, and from the Oligocene formation of Gurnet Bay, Isle of Wight, belonging to the British Museum, although originally in the collection of the late Rev. P. B. Brodie. The new British forms described include:—**Diptera**: *Riphidia brodiei*, *Mongoma cruciferella*, *Tipula gardneri*, *Bibio gurnetensis*, *B. oligocenus*, *Mesomyites* (new genus) *concinnus*, *Protoscinis* (new genus) *perparvus*. **Thysanoptera**: *Æolothrips brodiei*. **Neuroptera**: *Sisyra* (?) *disrupta*. The new American species determined include:—**Diptera**: *Plecia winchesteri*, from the Eocene (Oil Shales) of Colorado, and *P. explanata*, from the Florissant deposits, the latter formation having also yielded *Acreotrichites* (new genus) *scopulicornis*, *Rhamphomyia hypolitha*, *Urortalis* (new genus) *caudatus*, *Melieria atavina*, and *Anthomyia persepulta*. **Hymenoptera**: *Tæniurites* (new genus) *fortis* and *Heriades priscus*, both from the Florissant Miocene.

VII.—South Australia. Annual Report of the Government Geologist [L. Keith Ward] for 1915. Fol.; pp. 18, with maps and tables. Adelaide, 1916.

THIS report contains information on metallurgical subjects, water supplies, mineral resources, building stones, etc. A very important item of the year's work concerns the discovery of precious opal at Stuart's Range at a place situated 81 miles west by south of Anna Creek Railway Station. The specimens are stated to have been evidently derived from the Desert Sandstone formation which extends across Western Queensland and New South Wales into the northern portion of South Australia. Valuable notes on the building stones, which are regarded as Palæozoic and Tertiary, are set out in a series of tables at the end of the Report.

REPORTS AND PROCEEDINGS.

Geological Society of London.

May 16, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

A lecture on "British Geological Maps as a Record of the Advance of Geology" was delivered by Thomas Sheppard, M.Sc., F.G.S. He observed that geological changes were in many cases indicated on old topographical maps; consequently, very old plans and charts were of use in connexion with geological inquiries, although not strictly geological in character. Some examples of maps, dating from Elizabethan times, were exhibited, and they showed that in the Humber area great changes had taken place: in certain districts large tracts of land had been denuded, and many towns and villages had disappeared; in others, large stretches of reclaimed land marked places where water once stood. So long ago as 1595 writers were familiar with lithological differences in various parts of the country, and in 1683 Martin Lister read to the Royal Society a paper in which he definitely suggested "A Scheme for the Mapping of Soils and Rocks", wherein he mentioned the various kinds of rocks that occurred in Yorkshire; but his scheme was not actually carried out until a century later. Strachey (1719) and Packe (1743) produced some remarkable geological sections and plans.

The first systematic series of maps, illustrating the geological features of the counties, was issued in the Reports of the old Board of Agriculture, and dated from 1793 to 1822. These reports usually contained "soil-maps" of the counties described, upon which chalk, sandstone, limestone, peat, marl, gravel, etc., were shown by colours and shading. William Smith was certainly familiar with these "Agricultural Surveys", and doubtless they provided him with information that assisted him in the preparation of his great map of the geology of England and Wales, issued in 1815.

One of the earliest and most serious attempts to prepare geological maps was by Professor Jameson, who read a paper in 1805 "On Colouring Geognostical Maps" (Wernerian Nat. Hist. Soc., vol. i, published 1811); but the enormous number of complicated signs and symbols that he suggested proved unsuitable for practical purposes, although there were many good features in his colour scheme.

The first strictly geological map (now in the Society's possession) was apparently that made by W. Smith in 1799, showing the geological structure of the Bath District. This had been proved by the lecturer to have been coloured on a plan originally issued in *The New Bath Guide* of 1799. The first geological map of England and Wales was a small one, also by Smith, and it was presented to the Society by "the Father of English Geology" when the first Wollaston Medal was awarded to him in 1831. The lecturer discussed the history of the various maps and sections published by Smith, and described two hitherto unknown maps (of the counties of Durham and Northumberland) by the same author, in the Society's possession. He also exhibited one of the Scarborough district, found whilst he was cataloguing the Society's maps; all trace of this particular map had been lost for over eighty years. Smith's finest piece of work, his map of the Hackness district, dated 1832, apparently had not been seen by any worker since its publication, and the lecturer explained how he had recently been able to trace two copies. One of them, which was exhibited, he presented to the Society.

In the Society's possession also is an extensive and valuable collection of the maps of Greenough, both published and in manuscript. Among an extraordinary series of coloured maps of England and Wales, and of the British Isles, issued during the middle of the nineteenth century, those by Arrowsmith, Murchison, Walker, Ramsay, Ravenstein, Knipe, Phillips, and Johnston are especially noteworthy.

The Society's collection includes geological maps of Scotland and Ireland, some of great value and historical interest. Of Scotland, the remarkable series by MacCulloch, published and in manuscript, shows that the collection is by far the finest as regards early maps dealing with the geology of the country. A manuscript map of Scotland by Necker is dated 1808 (earlier than Smith's large map of England and Wales), and is undoubtedly the oldest. Among the maps of Ireland there is the fine series by Griffith, which includes a few examples not known by Judd or other writers on the subject.

As examples of privately published maps, those by Sanders of the Bristol Coalfield, Jordan's London District, and Elias Hall's Lancashire area were described. The lecturer concluded by referring to a catalogue of geological maps (other than the Geological Survey publications) which he had in course of preparation. This already contained details of approximately 3,000 maps.

June 6, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Geology of the Old Radnor District, with special reference to an Algal Development in the Woolhope Limestone." By Edmund Johnston Garwood, Sc.D., F.R.S., F.G.S., and Edith Goodyear, B.Sc.

The district comprises an inlier of Archæan grits and Woolhope Limestone forming an elongated dome bounded by Wenlock Shale. It was regarded by Murchison and the Geological Survey as consisting of Mayhill Sandstone succeeded conformably by Woolhope Limestone, and they attributed the unfossiliferous character of the sandstone and the abnormal facies of the limestone to alteration by igneous intrusions. Dr. Callaway, in 1900, first suggested that the so-called "Mayhill Sandstone" was of Archæan age, and recorded an unconformity at the base of the limestone. The authors confirm Callaway's views, and give evidence for correlating these Archæan rocks with Professor Lapworth's "Bayston Group" of the Longmyndian. The unconformable relation of the limestone to the Archæan is established in several portions of the district; while a study of the Trilobite and Brachiopod fauna of the limestone and included shale confirms the Wenlock age of the deposit. The most interesting fact brought out by a study of the limestone is the important part played in its formation by the calcareous alga *Solenopora* (of which a new species is described), the deposit constituting by far the most striking development of algal limestone yet recorded from British rocks. The limestone represents a reef facies of the normal Woolhope Limestone, being largely composed of Bryozoa and calcareous Algæ. Corals, although present, play only a subordinate part. The reef appears to have grown round a subsiding peninsula of Archæan rock, which evidently then formed the south-western continuation of the Longmynd range. The same reef facies is also found to occur at Nash Scar, three miles away to the north-east, where it rests on the Upper Llandovery Sandstone. The sudden change to the normal type of Woolhope Limestone at Corton, near Presteign, appears to mark the northern limit of this lagoon phase.

The paper concludes with an account of the movements that have taken place in the district, to which its general Caledonian trend is due.

2. "Correlation of Jurassic Chronology." By S. S. Buckman, F.G.S.

This paper owes its inception to certain discoveries made by the Officers of the Scottish Geological Survey during their investigations of the Jurassic deposits of the Isles of Raasay and Skye. The Ammonites and Brachiopods were sent to the author for examination, and the sequence of faunas which they disclosed necessarily led to comparison with results obtained in other areas—with Yorkshire, on which the author had recently written a palæontological chapter for a Geological Survey memoir, based largely on information and specimens submitted by the Survey; with the Dorset coast, helped by Mr. W. D. Lang's most painstaking work; with other areas within the author's field experience, helped largely by information most freely communicated by Mr. J. W. Tutcher. The results appeared to be so far-reaching that permission was asked of the Director of H.M. Geological Survey to lay before the Society a synopsis of the information obtained through the investigations of Survey Officers; this was kindly accorded, and the present paper is the outcome of research thus originated.

One of the principles utilized in this paper to ascertain or to surmise faunal sequence where precise information is defective, is that of what may be called "faunal dissimilarity"—that is, if the deposits of two neighbouring localities A and B, supposedly isochronous from their sequential position, show differing faunas, it is a reasonable inference that the faunas are not of the same date. Theoretical stratigraphical correlation has usually worked along these lines, but the principle involved has not been recognized by name. Now the principle is utilized, not only in regard to neighbouring localities, but even more widely, with suggestive results.

The paper is chiefly concerned with the Liassic Ages hitherto known as Domerian, Charmouthian, Sinemurian. In all of them there is proposed a considerable increase of the number of faunal horizons indicative of consecutive time-intervals, or hemeræ. In the case of the first no change of name is made; but in regard to the other two, subdivisions seem necessary, and each is apportioned into three Ages, as follows:—

Proposed Names.	*Old Terms.*
Hiviccian. Wessexian. Raasayan.	Charmouthian.
Deiran. Mercian. Lymian.	Sinemurian.

These, with the Domerian, each contain on an average about ten hemeræ, the grouping being controlled by the dominance of ammonite families of phases thereof—thus, Domerian: Age of Amaltheids; Raasayan: Age of Deroceratidæ and Echioceratidæ. It is obvious that, with this increase in the number of hemeræ, the number of local non-sequences is greatly increased. Some comparative diagrams illustrate this.

One of the most interesting discoveries which has resulted, partly from the great thickness of Scottish strata investigated and collected from, partly from comparisons with other areas, is that the so-called "*armatum* Zone" of the English Midlands and that of the Radstock district, of Yorkshire and of the Scottish Isles, are not isochronous, but are separated by a time-interval which corresponds to a thickness of some 300 feet of deposit in the Scottish area. Thus, instead of the simple descending sequence

Deroceras armatum,
Echioceras raricostatum,

there is this sequence ascertained:

An upper *Deroceras* horizon,
An upper *Echioceras* horizon in three distinct stages,
A lower *Deroceras* horizon,
A lower *Echioceras* horizon with some Armatoids;

and even now possibly this is not the end of the complication. This alternation of *Deroceras* and *Echioceras* involves a phenomenon which the author calls "faunal repetition", and it is a reasonable supposition that this is not a solitary case—that is to say, doubt is at once thrown on the contemporaneity of other so-called "zones" where they have been determined in different areas by the presence of certain species of a genus—the species admittedly not the same—or by the alleged presence of a single species on specific determination insufficiently rigid. The cases of zones determined on the *lucus a non lucendo* principle—the strata in correct intermediate position, but with the index zonal species conspicuously absent—seem especially to invite scepticism.

Three appendices are given—one, palæontological, containing descriptions of certain notable species, mostly new; another, historical, containing notes on certain ammonites described and figured by Wright in a paper published some years prior to the issue of his monograph: it affords clues to the interpretation of his species, to the recognition of some of his missing types, to the identity of certain figures in Reynès's monograph, and to the geographical distribution of species—a matter of particular importance in regard to faunal dissimilarity; the third, geological—a communication by Mr. J. W. Tutcher, embodying his reading of the sequence in the lower part of the Lower Lias carried down to the base of the Hettangian.

OBITUARY.

PROFESSOR ROBERT BELL,
I.S.O., M.D., D.Sc., LL.D., F.R.S., F.G.S.

BORN 1841. DIED JUNE 18, 1917.

PROFESSOR DR. ROBERT BELL, F.R.S. (formerly Chief Geologist of the Geological Survey of Canada, Ottawa), died suddenly on June 18, 1917, at Rathwell, Manitoba. Dr. Bell, who was 76 years of age, joined the Geological Survey of Canada in 1857, and subsequently made extensive topographical and geological surveys in various parts of the Dominion. He acted as Medical Officer, Naturalist, and Geologist combined on several expeditions to Hudson's Bay and Baffin Land. The Bell River, which he surveyed in 1895, was officially named after him. He also made the first surveys of some of the largest lakes in Canada. He was the Canadian correspondent of the Royal Scottish Geographical Society since its foundation.—*Westminster Gazette*, June 20, 1917.

THOMAS McKENNY HUGHES, M.A.,

Trinity College, Cambridge; Professorial Fellow of Clare College, Woodwardian Professor of Geology; F.R.S., F.S.A., F.G.S.; Chev. Ord. SS. Maur. et Lazar. Ital.; Corr. Memb. Soc. Geol. Belg., Soc. Geol. France, Germany, Italy, etc.

BORN DECEMBER, 1832. DIED JUNE 9, 1917.

WE deeply regret to record the death, on June 9, of our friend of fifty years—a frequent contributor to the GEOLOGICAL MAGAZINE—Mr. T. McKenny Hughes, M.A., F.R.S., Woodwardian Professor of Geology in the University of Cambridge, in his 85th year.

A life of Professor Hughes with a very excellent portrait appeared in the GEOLOGICAL MAGAZINE (N.S., Dec. V, Vol. III, No. 1, pp. 1–13, January, 1906).

The following appeared in the *Times*, June 11, 1917:—

Mr. T. McKenny Hughes "was born at Aberystwith, and was a member of a distinguished family. His grandfather, Sir Thomas McKenny, took a prominent part in Catholic emancipation in Ireland, his father became Bishop of St. Asaph, and one of his brothers is Bishop of Llandaff.

"Hughes was educated at Leamington and Llandovery Colleges, and took his degree at Cambridge in 1857 as a member of Trinity College. In 1860 he was appointed Secretary to the British Consul at Rome, and was left Acting Consul in that City in 1860 and 1861.

In the latter year he joined the Geological Survey of Great Britain and served on it until 1873, when he succeeded Professor Sedgwick as Woodwardian Professor of Geology at Cambridge. At first his survey work lay among the newer rocks of the south-eastern counties, but in 1866 he was transferred to the borders of the Lake District, where he did much important geological work.

"On going to Cambridge his duties as successor to the eminent Sedgwick were far from easy, but his varied attainments enabled him to discharge them with success. At the outset, in addition to the ordinary duties of his Chair, he devoted himself to three tasks which had connexion with his predecessor—namely, the adoption of the Cambrian system as defined by Sedgwick, the writing of the life of that geologist, and the erection of the Memorial Museum which has been built in his honour. The first of these would have reopened an unfruitful controversy, and Hughes wisely discontinued it. In carrying out the second he secured the services of the late Registrar of the University—Mr. J. W. Clark—and 'The Life and Letters of Sedgwick', by Clark and Hughes, appeared in two volumes in 1890. The performance of the third task was long delayed by many disappointments and difficulties, but Hughes had the satisfaction of seeing the completion of the Sedgwick Museum, which was opened by King Edward in 1904.

"During his tenure of the professorship Hughes did much original work in geology and archæology.[1] He was a fluent lecturer, but his most successful work as a teacher was due to his great capacity for arousing enthusiasm among his pupils, and many geologists owe their interest in the science to his efforts. He was elected a Fellow of the Royal Society in 1889, and received the Lyell Medal of the Geological Society in 1891, when he acknowledged the value of his intimate association with Sir Charles Lyell, with whom he made many geological tours during his early years. He was a Professorial Fellow of Clare College, and Chevalier of the Order SS. Maurice et Lazarus (Italy).

"He married, on November 28, 1882, Mary Caroline, daughter of the late Rev. G. F. Weston, Honorary Canon of Carlisle, and had three sons. Mrs. Hughes, who has herself done important geological work, was ever ready to assist her husband in the manifold duties of his professorship [see Mrs. Hughes' Memoir on the Pleistocene Mollusca of Cambridge, Geol. Mag., 1888, p. 193].

"As Sedgwick was elected Woodwardian Professor in 1818, he and his successor have between them occupied the Chair for ninety-nine years."

LIEUT. HORAS TRISTRAM KENNEDY, B.A., F.G.S.

Born 1889. Killed in action, June 6, 1917.

Lieut. Horas T. Kennedy, F.G.S., who was killed by shell-fire south of Ypres on June 6, was a geologist of great promise on the staff of the Geological Survey of Ireland, which he joined, after open

[1] [For a list of his papers up to 1906 see the life of Professor Hughes, as an "Eminent Living Geologist", Geol. Mag., 1906, pp. 10–13; the titles of ninety-three separate articles are there recorded.]

competition, in June, 1913. He was born in London, of Irish parentage, in 1889, and gained a senior scholarship at Trinity College, Cambridge, and a first-class in the Natural Science Tripos. On entering the Survey he was employed on the revision of the Leinster Coalfield, and was looking forward to work among Silurian strata in the West of Ireland, where his undoubted powers of original research would have been called forth. War, however, broke out, and he obtained a commission in the North Staffordshire Regiment, being transferred later to the Royal Scots Fusiliers. In the autumn of 1916 he married the second daughter of the Very Rev. C. T. Ovenden, Dean of St. Patrick's, Dublin; Mrs. Kennedy had already served for many months with a Voluntary Aid Detachment north of Étaples in France, including a winter partly spent in tents. At the close of 1916 Lieut. Kennedy was attached to the Royal Engineers for duties demanding scientific aptitude, and he was in command of a section at the time of his death. His keenness in geological work and his charm of personal manner make his loss deeply felt by his colleagues on the Survey Staff.

G. A. J. C.

UPFIELD GREEN, F.G.S.

Born August 4, 1834. Died May 31, 1917.

Our old friend Mr. Upfield Green, who had been failing for many months, passed away suddenly at Bristol. He was born in London, educated at Brighton and Neuweid, entered the London and County Bank in 1852, became Master at Stourbridge School in 1855, and the same year Overseer of the Wildberger Hütte. The mine stopped working in 1860, when Green returned to England and acquired the old printing business of Groom, Wilkinson & Co. He was an enthusiastic geologist, but wrote nothing, until after thirty years' observation and study of the geology of Cornwall had given him the key to the tectonics of that county. In 1904 he published "Note on the Correlation of some Cornish Beds with the Gedinnian of Continental Europe" (Geol. Mag., 1904); in 1909, "On the Geological Structure of Western Cornwall" (95th Rep. Roy. Geol. Soc. Cornwall), a paper which brought him the Bolitho Gold Medal; in 1912, "Note on the Pollurian-Trewavas Coast Section, Cornwall" (Geol. Mag., 1912); and in 1913, "On the General Geological Structure of Western Cornwall, with a Note on the Porthluney–Dodman Section" (Geol. Mag., 1913); the last two in conjunction with C. Davies Sherborn. He had the great satisfaction of knowing that his views on this difficult and controversial area were accepted by many of his friends, especially in Belgium, France, and Germany. He was materially assisted in his researches by his personal knowledge of the structure of the North of France, Belgium, and the Rhine, and his familiarity with the fossils of the Continental Devonian rocks. He became a Member of the Geologists' Association in 1886, and a Fellow of the Geological Society in 1889. He had held for many years a geological "At Home" once a month, when he gathered round him many friends.

C. D. S.

All Communications for this Magazine should be addressed to

THE EDITOR,

13 Arundel Gardens, Notting Hill, W. 11.

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. VIII.—AUGUST, 1917.

ORIGINAL ARTICLES.

I.—Cretaceous Mollusca from New Zealand.

By C. T. Trechmann, D.Sc., F.G.S.

(*Concluded from the July Number, p. 305.*)

(PLATE XXI.)

Aplustrum (?) Selwynensis, sp. nov. (Pl. XXI, Figs. 1–3.)

SHELL oval in shape, very thin, consisting of six whorls, the last one very large and inflated. In some specimens the spire is rather prominent, in others slightly depressed with rather deep sutures. The apex and protoconch when not broken off are pointed and prominent. The aperture is broad in front but narrow behind, and seems to have a faint shallow anterior channel. There is no columellar fold. The outer lip in specimens where it is preserved is sharp and very slightly flattened out and expanded anteriorly. The growth-lines are fairly prominent, and there is a tendency for faint and shallow parallel furrows to develop, especially on the anterior portion. Height about 18 mm.

This fragile shell is rather common, but often more or less crushed. *Aplustrum* is the only genus to which I can refer it, but compared with a recent specimen of *A. amplustre* it has a more prominent protoconch, which in the recent form is rather sunken and buried. The shell of the recent form also is smoother and more glossy.

Wilckens illustrates a shell (*Bulla subglobosa*)[1] viewed from the mouth side, from Quiriquina, which recalls the present form if seen in a similar position and may possibly be identical. It cannot, however, be a true *Bulla* as he says the spire is only slightly depressed, while a characteristic feature of *Bulla* is the deeply sunken and hidden spire.

I have also compared my specimens with the original illustrations of *Bulla subglobosa* and *Philine chilensis* of Philippi[2] and find that they do not resemble the figures of either, as in both of them the last whorl appears more swollen and the spire more sunken. It also recalls *Bulla glacialis*, Wilckens,[3] from the Tertiary beds of Seymour Island, Antarctica, which, as Wilckens remarks, is very like though more swollen than *B. subglobosa* of the Cretaceous of Quiriquina, but

[1] N.J. für Min., Beil. Bd. xviii, pl. xviii, fig. 11, 1904.
[2] Tert. u. quart. Versteinerungen Chiles, 1887, pl. xiii, figs. 2*a*, *b*, 4.
[3] "Die Mollusken der Antarkt. Tertiarformation": Wissensch. Ergebn. der Schwed. Sudpolar Exped., p. 29, pl. i, figs. 36*a–c*, 1911.

none of the figures show the elevated protoconch of the New Zealand shell.

Locality.—Selwyn Rapids, rather common in one piece of rock.

Holcodiscus (Kossmaticeras) gemmatus, Hupé. (Pl. XXI, Fig. 6.)

Ammonites gemmatus, Hupé, Gay's Hist. Chile, 8, 35, pl. i, fig. 3, 1854.
Holcodiscus gemmatus, Hupé, Steinmann, "Ceph. d. Quiriquina Schichten": N.J. für Min., Beil. Bd. x, p. 68, pl. vi, figs. 1*a*, *b*, 2*a*, *b*, 1895.
Wilckens, "Revision d. Fauna der Quiriquina Schichten": N.J. für Min., Beil. Bd. xviii, p. 187, 1904.
Kilian et Reboul, "Les Céphalopodes Néocrétacés des îles Seymour et Snow Hill": Wissensch. Ergebnisse der Schwed. Sudpolar Exped., Stockholm, 1909.

A fragment of an Ammonite was obtained at Selwyn Rapids, but owing to the blasting operation only about a third of the sutured portion of the last whorl could be found. It has been partly crushed and the sutures cannot be made out without destroying the specimen, but the outer shell with its ornamentation is very well preserved. The last whorl embraces about half the previous one and the umbilical slope is steep, almost vertical. The venter is rounded and the ribs cross it with great regularity. They are equally spaced on the venter, but are less regular on the sides. Only about half the number of ribs that cross the venter reach the umbilical shoulder, approximately every alternate rib disappears rather less than halfway from the venter to the umbilical slope. Of those that continue two or occasionally three unite at the umbilical shoulder to form a series of rather closely spaced sharp oval nodes whose apices are directed backwards. The ribs are slightly sinuous on the sides.

This fragment agrees so closely in external ornamentation with the examples figured from Quiriquina and Antarctica that there can be no doubt of its identity. It is common in the Upper Cretaceous of Seymour Island, but has not been found in South Patagonia, where, however, the three Indian species, *H. Theobaldinus*, *Bhawani*, and *Æmilianus*, all of Stoliczka, occur. In addition to the three forms just mentioned the Aryalur Beds of the Indian Senonian yield the closely allied species, *H. Madrasinus*, Stol., *Kandi*, Stol., and *Kalika*, Stol.

Locality.—Selwyn Rapids, one specimen.

Belemnites sp. (Pl. XXI, Fig. 9.)

A single Belemnite fragment was collected at Selwyn Rapids. It measures 24 mm. in length and forms the terminal part of a guard, but no trace of phragmocone remains. It seems to have been rolled and is split in two pieces longitudinally. The rock adheres so closely to the outer surface that very little of this is visible. In size and shape it resembles very closely some more or less rolled fragments of Belemnite guards that occur at Brighton, 12 miles south of Dunedin, in a hard pebbly shell bed resting almost directly on the coal, which rests in turn on the eroded schists. Hector called this fossil *Belemnites Lindsayi*. The bed was classified as Tertiary by the earlier New Zealand geologists, but this correlation will probably have to be revised, and Professor Marshall is inclined to correlate it with the Wangaloa Bed. The other fossils in it seem to be very poorly preserved. Professor Marshall sent some specimens of these Belemnites to Wilckens, who submitted them to other specialists. Their opinion was that they were too much rolled for accurate identification, but were certainly true Belemnites.

The present fragment, though clearly a true Belemnite, is too poorly preserved for further determination, but its occurrence among the fauna of Selwyn Rapids is significant. For comparison I illustrate two specimens of the Brighton Belemnite (Pl. XXI, Figs. 7, 8) which were kindly given to me by Professor Marshall.

Correlation.

The limited number of fourteen fossils under examination in the present paper indicates the absolute agreement of the Cretaceous of New Zealand with that of the rest of the Indo-Pacific region.

The *Conchothyra parasitica* beds at Selwyn Rapids and the Waimakariri Gorge are clearly of the same age and correspond very closely with the *Pugnellus* and *Trigonia Hanetiana* beds of Quiriquina in Chili and the *Pugnellus* and *Aporrhais gregaria* beds of South Patagonia. There can be no doubt that the *Pugnellus* bed in the Waipara Gorge is also of approximately, if not of exactly similar, age.

Steinmann[1] says, "The Quiriquina Beds of South Chili are of the same age as the upper division of the European Senonian, and definite faunal relations exist between them." Wilckens[2] regards the South Patagonian higher Cretaceous beds as the equivalent or at least the analogue of the Quiriquina of Chili.

It is thus a matter of interest to find in the same bed at Selwyn Rapids in New Zealand species such as *Aporrhais gregaria*, which occur in South Patagonia but not at Quiriquina, and *Holcodiscus* (*Kossmaticeras*) *gemmatus*, which is found at Quiriquina but not in South Patagonia, but which recurs at Seymour Island off the coast of Graham Land in Antarctica.

The reported identification by Mr. Woods of a Gault fauna in New Zealand has already been mentioned. It may turn out that beds closely resembling those with *Inoceramus Steinmanni* in South Patagonia will also be found. It remains to be seen when Professor Marshall's work on the Wangaloa fossils is published whether this fauna, which should apparently be of Maestrichtian age, finds any close parallel in South America or elsewhere.

I found no Tertiary species among the Upper Senonian fossils of New Zealand which I examined. Some Tertiary forms might be expected to occur in the Wangaloa Beds, but for details of these I await Professor Marshall's report.

The number of Upper Senonian forms common to New Zealand, South America, and Graham Land points to a much closer connexion between these regions than obtains at the present day, and indicates a land mass or a group of islands in the South Pacific joining New Zealand to South America previous to the Tertiary uplift of New

[1] N.J. für Min., Beil. Bd. x, p. 27, 1895.
[2] Bericht der Naturgesell. Freiburg, 1907, Bd. xv, p. 63.

SYNOPSIS OF PALÆONTOLOGY.

NAME.	LOCALITY.	HORIZON.	AFFINITIES.
Trigonia cf. *Hanetiana*, d'Orb. (Pl. XXI, Fig. 5).	Waimakariri Gorge.	Upper Senonian.	Hector's *Trigonia sulcata*, apparently identical with *T. Hanetiana*, common at Quiriquina in Chili.
Dentalium sp. (Pl. XXI, Fig. 10).	Selwyn Rapids.	,, ,,	Resembles *D. Chilensis*, d'Orb., of Quiriquina.
Natica (*Euspira*) *variabilis*, Moore (Pl. XIX, Figs. 8–10).	,, ,,	,, ,,	Occurs in Lower and Upper Cretaceous of Australia, and is found in the opal beds of New South Wales.
Chrysostoma Selwynensis, sp. nov. (Pl. XXI, Figs. 4*a*, *b*).	,, ,,	,, ,,	Apparently new form.
Turritella sp. (Pl. XIX, Fig. 11).	,, ,,	,, ,,	Too imperfect to determine specifically.
Neritopsis (?) *Speighti*, sp. nov. (Pl. XIX, Figs. 12–15).	,, ,,	,, ,,	Recalls *Vanikoro Kiliani*, Wilckens, of the Upper Cretaceous of Antarctica, but is much larger.
Conchothyra parasitica, McCoy (Pl. XX, Figs. 4, 5).	Selwyn Rapids and Waimakariri Gorge.	,, ,,	Apparently peculiar to New Zealand.
Pugnellus Marshalli, sp. nov. (Pl. XIX, Figs. 1–4).	Selwyn Rapids.	,, ,,	,, ,, ,, ,,
P. Waiparensis, sp. nov. (Pl. XX, Figs. 1*a*, *b*).	Waipara Gorge.	,, ,,	Resembles *Pugnellus Hauthali*, Wilckens, of the Upper Cretaceous of South Patagonia.
P. australis, Marshall (Pl. XX, Figs. 2*a*, *b*, 3*a*, *b*).	Wangaloa.	Maestrichtian (?).	Apparently confined to the Wangaloa Beds of New Zealand.
Alaria Suteri, sp. nov. (Pl. XIX, Fig. 5).	Selwyn Rapids.	Upper Senonian.	Apparently a new form.
Aporrhais gregaria, Wilckens (Pl. XIX, Figs. 6–7).	,, ,,	,, ,,	Occurs in Upper Cretaceous of South Patagonia, but not at Quiriquina.
Aplustrum (?) *Selwynensis* (Pl. XXI, Figs. 1–3).	,, ,,	,, ,,	Recalls *Bulla subglobosa*, Philippi, of the Upper Cretaceous of Quiriquina, and *B. glacialis*, Wilckens, of the Tertiary of Antarctica.
Holcodiscus (*Kossmaticeras*) *gemmatus*, Hupé (Pl. XXI, Fig. 6).	,, ,,	,, ,,	Occurs at Quiriquina and Seymour Island in Antarctica, but not in South Patagonia.
Belemnites sp. (Pl. XXI, Figs. 7–9).	,, ,,	,, ,,	Resembles *Belemnites Lindsayi*, Hector, from Brighton, 12 miles south of Dunedin.

Zealand or of the South American Cordillera. This connexion probably included a portion of the present continent of Antarctica.

In contrast to the large number of forms common to South America and Seymour Island the slightness of the connexion with the Australian Upper Cretaceous is shown by the presence of only one Australian Gasteropod, *Natica* (*Euspira*) *variabilis*. This seems to be the sole connecting link in the molluscan fauna with the much nearer continent of Australia. Eight species out of fifteen seem to be confined to New Zealand. The Upper Cretaceous of New Caledonia is yet very little known, but according to Haug *Kossmaticeras Bhavani*, of the Aryalour group of India, has been found, and so it is possible that some forms at present thought to be restricted to New Zealand may occur there.

I am indebted to Dr. A. Smith Woodward for the following notes on some fish-scales discovered with the Cretaceous fossils described above:—

"The largest scales are evidently referable to Berycoid fishes. They are much deeper than broad, with a relatively small and somewhat thickened exposed sector. The best-preserved specimen is shown of the natural size in Pl. XXI, Fig. 11*a*, with a portion enlarged four times in Fig. 11*b*. Its extensive covered area is marked by the very fine and numerous concentric lines of growth, which tend to subdivide into minute granules near the edge of the exposed area (Fig. 11*b*). It is also slightly impressed with a few grooves which radiate forwards and produce a waviness in the concentric lines of growth where they cross them. The small thickened exposed area of the scale is ornamented with comparatively large and rounded radiating ridges, which are feebly marked for the greater part of their extent, but become raised into irregular elongated tubercles near the anterior overlapped margin (Fig. 11*b*). The free posterior border of the scale is somewhat obscured by matrix, but does not appear to have been sharply serrated. Part of an apparently similar scale is clearly only wavy, not serrated, at the posterior border.

"A smaller scale, more incompletely preserved, is shown of three-halves the natural size in Pl. XXI, Fig. 12*a*, with a fragment of its exposed area enlarged four times in Fig. 12*b*. The tissue is a little disintegrated, but it displays the very fine concentric lines of growth and the few radiating grooves in its covered area; while the hinder border of its comparatively smooth exposed area bears coarse sharp serrations and pectinations impressed again by the fine concentric lines of growth. The imprint of the inner face of the scale seems to show traces of the irregular tuberculation which has already been noticed on the inner face of the scales of the Berycoid *Hoplopteryx*.

"Another well-preserved fish-scale, shown of twice the natural size in Pl. XXI, Fig. 13, may be regarded as belonging to an Elopine Clupeoid. Its large covered area, displaying extremely fine concentric lines of growth, is crossed by numerous sharp radiating grooves which have become clefts by crushing. Its denser exposed area is nearly smooth, but bears faint traces of a few radiating lines.

Usually in the scales of Elopines the radiating ornament on the exposed area is more conspicuous than in this case; but similarly feeble markings are observable on a scale in the type-specimen of *Thrissopater megalops* from the English Chalk.

"The fossil fish-scales from New Zealand thus belong to groups of teleostean fishes which are abundant in Cretaceous formations in other parts of the world."

EXPLANATION OF PLATE XXI.

1–3*b*. *Aplustrum Selwynensis*, sp. nov. Selwyn Rapids. Fig. 3*a* × 1½ nat. size; Fig. 3*b* × 5 nat. size.

4*a*, *b*. *Chrysostoma Selwynensis*, sp. nov. Selwyn Rapids. × 3 nat. size.

5. *Trigonia* cf. *Hanetiana*, d'Orb. Waimakariri Gorge.

6. *Holcodiscus* (*Kossmaticeras*) *gemmatus*, Hupé. Selwyn Rapids.

7, 8*b*. *Belemnites* sp. Brighton, south of Dunedin. Maestrichtian (?). Fig. 8*b* × 1½ nat. size.

9. *Belemnites* sp. Selwyn Rapids. × 1½ nat. size.

10. *Dentalium* sp. Selwyn Rapids. × 2 nat. size.

11. Berycoid fish-scale, outer view, natural size (11*a*), with portion of adjoining covered and exposed areas enlarged four times (11*b*).

12. Fragments of Berycoid fish-scale, outer view, preserved on inner impression of same, three-halves natural size (12*a*) with portion of exposed area enlarged four times (12*b*).

13. Elopine fish-scale, outer view, twice natural size.

[Plates XIX and XX appeared in the July Number.]

On Pl. XX, Figs. 1*a* and *b* and 3*a* and *b* should be transposed, an unfortunate error having occurred in the numbering. The specimen figured at the left-hand top corner really represents *Pugnellus Waiparensis*, sp. nov., and that at the right-hand top corner represents the normal form of *Pugnellus australis*, Marshall, from Wangaloa.

NOTE.—In some of the copies the following correction is needed at the foot of Plate XIX, which appeared in the July Number GEOL. MAG., next p. 304: for CRET EOUS *read* CRETACEOUS (two letters AC having accidentally fallen out).—ED. GEOL. MAG.

II.—MORPHOLOGICAL STUDIES ON THE ECHINOIDEA HOLECTYPOIDA AND THEIR ALLIES.

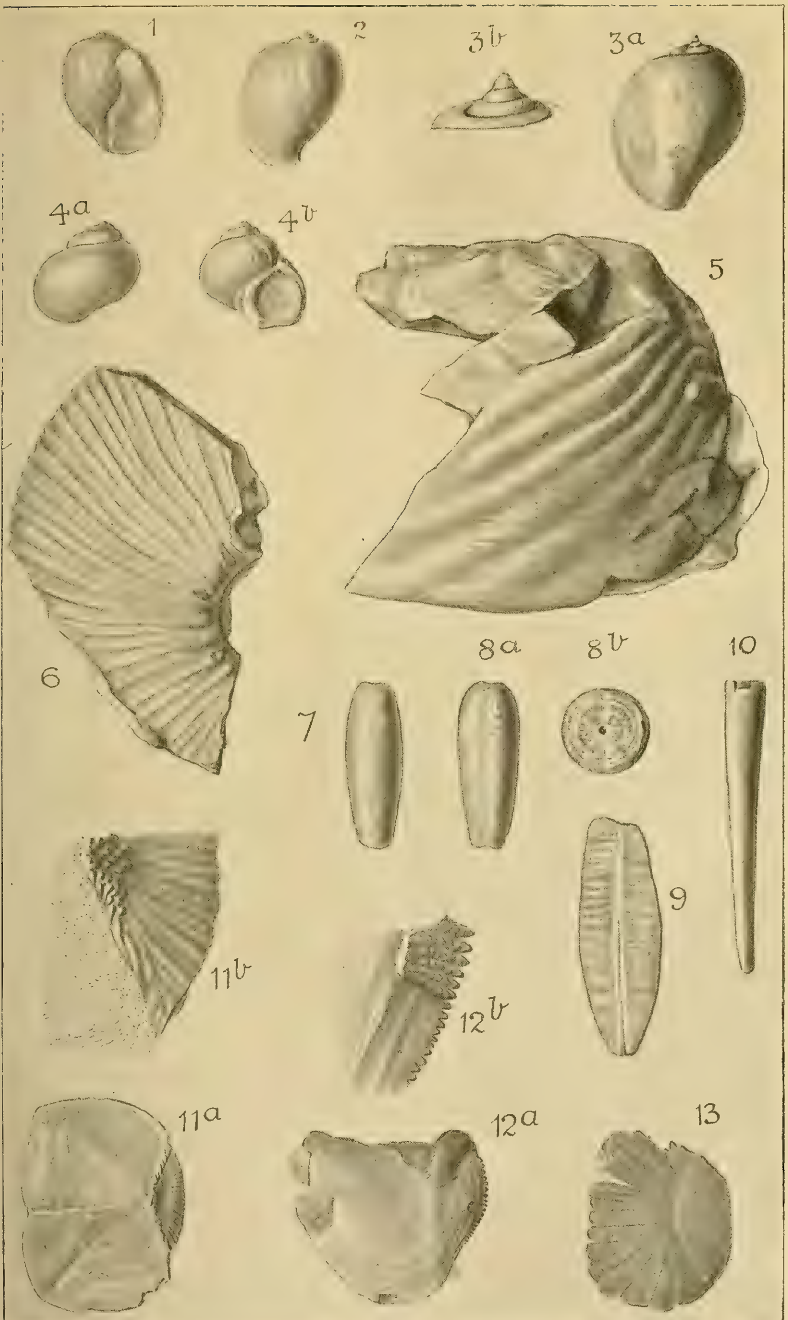
By HERBERT L. HAWKINS, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

IV. THE PERIGNATHIC GIRDLE OF THE PYGASTERIDÆ.

(WITH FIVE TEXT-FIGURES.)

1. INTRODUCTION.

THE examination of the internal structures of Jurassic fossils is attended with considerable technical difficulties. Even in cases where the surrounding matrix is sufficiently friable for the development of the external surface, the infilling material is usually either thoroughly indurated or irregularly nodular in texture. Internal moulds may be readily procured, both by natural weathering and artificial processes. But such preparations, though adequate for the investigation of shallow impressions such as the muscle-scars of Pelecypoda, are of uncertain service for the study of structures with



G. M. Woodward, del. *Bale & Sons, imp.*

UPPER CRETACEOUS FOSSILS, NEW ZEALAND.

high relief. Specimens of *Pygaster semisulcatus* (olim "*P. umbrella*") are frequently found in the Corallian of Berkshire in the state of decorticated moulds, and in such examples the presence of strong perignathic prominences is indicated by deep pits on the adradial sides of the branchial incisions. But attempts to reproduce these perignathic structures by gutta-percha casts have hitherto proved unsuccessful. The pits are so deep that it is almost impossible to ensure their perfect emptiness; and they are internally expanded and curved. For these reasons our knowledge of the perignathic girdle of the Jurassic Holectypoida has up to the present been practically confined to a realization that such a structure existed in robust development. Lovén ("Recent Form of the Echinoconidæ" and "Echinologica") ascertained something of its character by means of sections, but was able to examine the more prominent features only.

After many failures, I have succeeded in exposing the girdle, with varying completeness, in two fully grown specimens of *Plesiechinus ornatus* (olim *Pygaster semisulcatus*) from the Aalenian (Pea Grit) of Leckhampton. In many examples there is a cylinder of fairly yielding matrix connecting the apertures of the periproct and peristome, while the limestone wholly sheltered by the test is in a very refractory state. In the two specimens on which this paper is based, the soft plug, though containing many pisolite grains, was slightly greater in diameter than the peristome; and so it was possible, by slicing off the adapical surface, to expose all of the perignathic structures in one instance and the adoral parts of them in the other. The more completely developed specimen is now in the collection of the Geological Department, University College, Reading, registered number 924.

The structures shown in the prepared specimens have a special interest in view of the primitive qualities of the genus *Plesiechinus*. In the present paper a brief comparison is made between the perignathic girdle of the Pygasteridæ and that of the simpler types of the Diademoida (Centrechinoida). For the purpose of this comparison I have used Jackson's summary and diagrams given in his "Phylogeny of the Echini", pp. 189–195, reinforced by a few observations of my own. A detailed comparison with the later Holectypoida and the Clypeastroida (in which, thanks to the work of Lovén and Duncan, the girdle is already well known) is postponed to a later paper partly prepared.

2. The Perignathic Girdle of *Plesiechinus ornatus*.

(a) *The relations of the basi-coronal plates.* (See p. 344, Fig. 1.)

The peristome of *Plesiechinus* (and of all Jurassic Pygasteridæ) is approximately circular in outline, but the circumference is strongly "festooned" by profound branchial incisions. These incisions, as is usual in Ectobranchiate Echinoidea, involve those parts of the interambulacral margin that are contiguous to the ambulacra. As may be seen by reference to Fig. 1, the branchial incisions are not equidistant, the measurement across an ambulacrum being greater than that across an interambulacrum. The actual

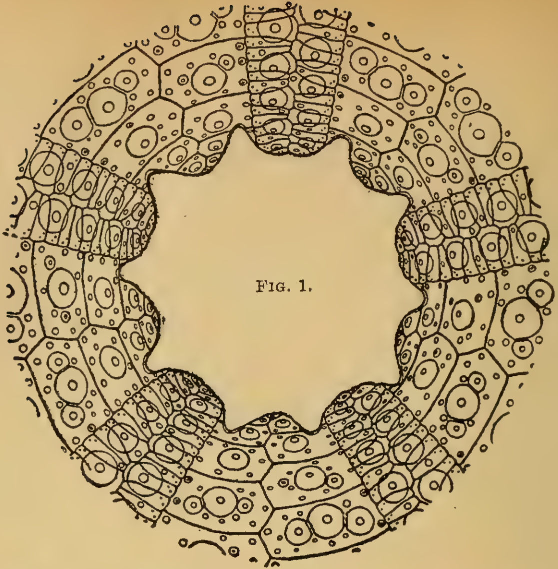


FIG. 1.

FIG. 3.

FIG. 4.

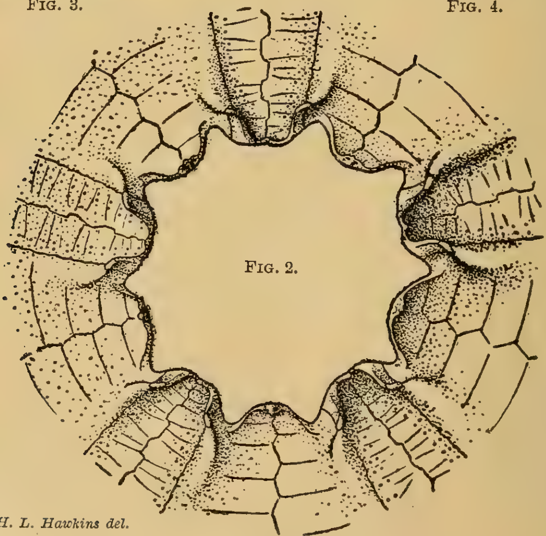


FIG. 2.

H. L. Hawkins del.

FIG. 1. Peristome of *P. ornatus*, external view. × c. 3.
,, 2. ,, ,, ,, internal view. × c. 3. Coll. Univ. Coll., Reading, Geol. Dept., No. 924. The figure is partly restored, several of the processes having been broken during development.
,, 3. Oral aspect of a pair of processes. × c. 6.
,, 4. ,, ,, an interradial "ridge". × c. 12.

amount of peristomial circumference (reduced to a simple circle) built up by the two areas is approximately the same, but the interambulacral portion is entrenched upon by the branchial incisions. The ambulacra present a semi-elliptical margin to the peristome, while that of the interambulacra is more nearly semicircular. The ambulacral pores, which are not crowded nor much displaced from their direct line, pass down near to the adradial sides of the branchial incisions, and curve round with the margin of their areas.

The primordial, unpaired plate of the interambulacrum is preserved as a small, triangular ossicle. The interradial sides of the branchial incisions are formed of the edges of two or three paired interambulacral plates, and the single plate occupies only the apex of the semicircular margin of the area. Lovén ("Recent Form of the Echinoconidæ") recognized the persistence of the unpaired plate in *Plesiechinus*.[1] It is interesting as showing that this typically Spatango-Clypeastroid feature was developed at the very outset of "Irregularity".

A slight groove extends along the border of the interambulacrum from the branchial incision to nearly half-way across the adoral surface. It is marked by the absence of large ornament, the presence of guttate granules, and the development of small pits on the transverse sutures. As will be seen later, this specialized region coincides in position with a definite internal structure.

The adoral surface of *Plesiechinus* is slightly concave, but at a region nearly coincident with the position of the apices of the branchial incisions a decided, though short-lived, invagination sets in. Thus the basi-coronal plates at the peristomial border are almost vertically disposed. All the plates of the adoral surface are surprisingly thin, even in large and gerontic individuals where the adapical plates are massive.

(b) *The ambulacral processes.* (See p. 344, Figs. 2, 3.)

These structures have been partially described by Lovén (loc. cit.). They present an anomalous appearance when partly cleared of matrix. They seem to be massive, ridge-like prominences, situated obliquely to the radius across the actual adradial suture, and to possess an escarpment-like adoral end, with a steep "dip-slope" passing adambitally and soon merging into the general inner surface of the test. They obviously spring from the ambulacrum near the peristomial margin, but are quite as clearly based upon the interambulacral plates for the greater part of their extent. When the preparation of the specimen is complete the explanation of this peculiar anomaly is seen. The actual process is a slender, lath-like projection rising from the ambulacrum near the adradial margin and

[1] Lovén (Études, pl. xiv, figs. 124 and 125) has shown the primordial interambulacral also in *Holectypus* and *Discoides*. It is almost unnecessary, if not presumptuous, to confirm the accuracy of Lovén's observations on Echinoid structures; but in the case of his fig. 124 (*Holectypus*) I have a prepared specimen which agrees with his drawing in even the minutest particulars.

leaning outwards towards the interambulacrum, though practically vertical when viewed from the branchial incision. The process is narrow at the base, and a little broader at the summit, where it is capped by an ovoid expansion which overhangs its sides. It leans against, and is visibly sutured to, a much more massive buttress which is almost wholly interambulacral in position, and constitutes the "dip-slope" of the whole structure. Lovén ("Echinologica") seems to have ascribed this buttress to the ambulacrum in its entirety, but this is contrary to my observations. His meaning is rather difficult to follow in the passage (loc. cit., p. 51) dealing with this structure. The buttress has a rounded crest, which overhangs, in a slight eave, the concave hollowing of its side adjacent to the branchial incision. The whole buttress, at first directed in a line continuous with that of the process, gently curves back towards the adradial suture, near to which, but on the interambulacral side, it passes until it sinks to the general level of the test. The position of this buttress is indicated externally by the specialized smooth area referred to above (section 2, a). The texture of the stereom of the buttress is different from that of the process, the former being soft and friable, while the latter is almost porcellanous. It is obvious that the buttress is no part of the perignathic girdle strictly speaking, but is merely a strengthening structure for the better support of the process, and the stiffening of the extremely thin plates in the region of the peristomial invagination.

In the more important specimen, the diameter of which is 74 mm. (the peristome being 12 mm. across), the average height of the processes, measured from the internal surface of the test at their base, is almost exactly 3 mm. The interradial buttresses extend towards the ambitus for a distance of about 8 mm. from the apices of the branchial incisions.

The ambulacral pores pass between the bases of two processes without perforating them and without being deflected from their straight course. They pierce the test very obliquely near the peristome, but otherwise show no disturbance due to the processes. I have seen no trace of a suture at the base of any of the twenty processes examined, but these lines are so faint on even recent tests that there is no reason to doubt their occurrence.

In the perradial line, just at the peristomial margin, there is a small ovoid prominence or thickening of the invaginated edge of the ambulacrum. This unpaired structure is probably not a part of the girdle, in as far as that apparatus serves as a support for the jaw-muscles. Of itself the prominence is of trifling importance, but a similar thickening of much greater relative size occurs in *Conulus*, so that its presence in *Plesiechinus* seems worth recording.

(c) *The interradial "ridges"*. (See p. 344, Text-figs. 2, 4.)

At first sight the perignathic girdle seems to be composed solely of the ambulacral processes above described, the equivalents of the ridges (Duncan) or apophyses (Jackson) being so feebly developed. There is a slight thickening of the test along the margins of the branchial incisions, but this is presumably for the purpose of affording a safe exit for the branchiæ, and has nothing to do with the jaw-apparatus. But on careful investigation it is seen that the invaginated rim of the primordial interambulacral plate is thickened, and leads up by a concave curve to a small, rounded prominence which lies in the median interradial line. There is, in fact, a very slight ridge, extending across the projecting portion of the interambulacral margin, and culminating in a central prominence whose axis is considerably inclined from the vertical. At each side of the central knob (which is less than one-sixteenth of the height of the ambulacral processes), the "ridge" shows a slight drop, as if to render the prominence more conspicuous. A very delicate, blunt carina passes adorally from the knob to the margin of the peristome, dividing the concave slope of the ridge into two halves. As far as I have been able to determine, the adambital side of the ridge is slightly undercut, so that it overhangs the interambulacrum. In this respect, as in the development of a median carina, this feeble section of the perignathic girdle resembles that of many Diademoida. The homologies between its several parts and those of the Cretaceous Holectypoida will be discussed in the forthcoming paper to which reference has already been made.

(d) *The distribution of the lantern-muscles.* (Fig. 5.)

The lantern of *Plesiechinus* is at present unknown as regards its detailed structure. That of *Discoides* only, among the Holectypoida, has been adequately described. It is, however, quite unnecessary to argue the question of its presence or absence in the Jurassic genus. During the development of one of the girdles above described, I cut through certain delicate Echinoid ossicles which were without doubt portions of pyramids, but the refractory nature of the matrix made it impossible to see any but sectional views of them. For the purpose of reconstructing the musculature of the jaw-apparatus it is necessary and reasonable to suppose that the lantern was essentially similar to that of the Diademoida, with tendencies in the direction of that of *Discoides* and the Clypeastroida.

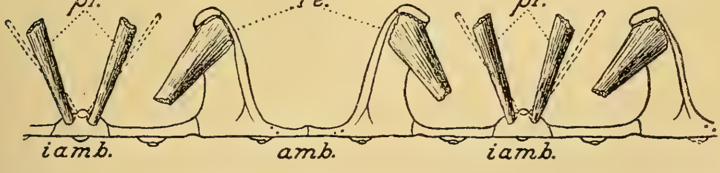


FIG. 5.—Schematic restoration of the attachment of the lantern muscles to the perignathic girdle in *Plesiechinus*. *pr.* protractors, *re.* retractors. The hypothetical radial compass muscles are indicated by double broken lines.

There can be little doubt that the retractor muscles were attached to the upper parts of the ambulacral processes, on their interradial faces. Retractors based upon the two sides of an arched "auricle" serve hemi-pyramids belonging to two separate maxillæ, and so normally diverge. The planes of the interradial faces of the processes in *Plesiechinus* are themselves directed away from one another, so that a divergent pair of retractors could spring from them practically at right angles to the articulating surface.

The protractor muscles must have been based either upon the incipient ridges (as they would be in Diademoida), or else far back and low down on the interradial sides of the processes (after the manner of Clypeastroida). The feebleness of the interradial elements of the girdle in *Plesiechinus* would tend to suggest the latter alternative, but nevertheless I incline to believe that they had the former position. In *Discoides* and *Conulus* there is no "interradial face" to the process, which rests against, and is sutured to, a ridge-like thickening of the test of practically the same height as itself. And the two concave bays, resembling "combes" on an escarpment, that occur on the adoral surfaces of the small ridges, seem to demand an explanation which is most satisfactorily given by calling them muscle-impressions. *Plesiechinus* is far more like a Diademoid than a Clypeastroid in general characters, so that the balance of probability would place the protractors on the ridges, insignificant though they are.

The only other series of jaw-muscles that are attached to the perignathic girdle in Diademoida are the slender "radial compass muscles", which diverge from the forked ends of the compasses. They spring from the ridges, above and behind the protractors, in the Regularia Ectobranchiata. The two slight depressions on each side of the central interradial knob are extremely suggestive of sites for the attachment of these muscles. But if the depressions had this purpose their presence would imply the existence of compasses in the lantern of *Plesiechinus*. Compasses are not known in *Discoides* (though their fragile nature might well account for their non-preservation), and they are definitely absent from the Clypeastroid lantern. The existence of radial compass muscles in *Plesiechinus* must therefore be regarded as problematical. In the accompanying restoration, I have inserted them as dotted lines in the position that they would presumably have occupied if they were developed.

There is no indication of the existence of any additional retractor muscles, such as occur in the Clypeastroida, but on the other hand there is no reliable proof of their absence. The processes, apart from their supporting buttresses, are so slender that they seem unlikely to have given support to more than the single retractors.

3. The Perignathic Girdle of *Pygaster* and *Holectypus*.

As far as can be judged, there is no essential difference in the position and relative proportions of the elements of the girdle in *Pygaster semisulcatus* from that already described. I have studied the apparatus only from internal moulds of this species.

In *Holectypus hemisphæricus* and *depressus* I have succeeded in clearing the inner parts of the peristome sufficiently to reach the adoral edges of the processes, which are like those of *Plesiechinus* in all the features shown. By means of serial sections, it has been possible to recognize that the whole girdle, in both species, is practically identical with that already described. The buttresses have similar characters in all three genera, but seem to be shorter and steeper in *Pygaster*, and less massive in *Holectypus*. In both the genera last named the plates of the adoral surface are exceedingly thin—more so proportionately than in *Plesiechinus*—so that actual development of the inner surface is a matter of great difficulty, even when the outer surface is still encased in matrix. The infilling material is generally completely indurated in *Holectypus*, and when a band of less refractory rock is found it proves to be a thin film in contact with the test along a narrow belt connecting the peristome with the periproct.

4. A comparison between the Perignathic Girdle of *Plesiechinus* and that of primitive Regular Echinoidea.

The perignathic girdle of *Plesiechinus* is definitely Diademoid (Centrechinoid) in character, and shows no affinity to the Cidaroid type. That is to say, its major elements are situated on the ambulacral plates; the interradial ridges of the Cidaroida being practically unrepresented. The interradial buttresses have evidently no homology with the Cidaroid ridge, being behind the true girdle, and having a merely mechanical function for the better support of the fragile adoral surface. They reach their fullest development in *Discoides* and the Clypeastroida. The sudden and complete transference of the "auricle" from the interambulacrum to the ambulacrum, which accompanied the change from the Cidaroida to the Diademoida, is one of the chief gaps still unbridged in the evolutional history of the Echinoidea. The process was absolutely completed in the Pygasteridæ.

The two vertical, unarched processes on the ambulacrum are in keeping with the general Jurassic character for the girdle. The Calycina, *Hemicidaris*, *Pseudodiadema*, *Stomechinus*, and even the Cretaceous *Cyphosoma* all possess "disjunct" auricles. And in all the genera except the last named the interradial portions of the girdle are very feebly developed. These features are morphogenetically neanic, or perhaps nepionic; the girdles of later Echinoids which possess elaborate structures all passing through a stage comparable with this Jurassic phase. The central knob on the ridge is a feature very constantly found in those Diademoida which have interradial developments of the girdle (e.g. *Salmacis*).

But in three important respects the Pygasterid girdle differs from that of the Diademoida. The processes are situated at the extreme interradial edges of the ambulacra, and are not perforated by the ambulacral pores. In the Diademoida the processes often spring from expanded bases which involve practically the whole width of the ambulacral columns, and are in consequence passed through by the podial pores. In *Plesiechinus* the processes are inclined away from the margin of the peristome, while in the Diademoida they rise directly from, and almost at right angles to, the margin. And lastly, the processes of the Pygasteridæ, so far from converging across the ambulacrum, actually diverge, while Diademoid processes, even when they do not meet in an auricular arch, are always inclined towards one another.

These three points of difference are all in a sense prophetic of the subsequent perignathic changes in Holectypoida and Clypeastroida. The wide basal separation and increasing divergence of the processes suggest the future shifting of these structures to an interradial convergence as seen in *Clypeaster*, and more completely in *Echinocyamus* or *Echinarachnius*. The situation of the processes of *Plesiechinus* well back from the peristomial margin is found in a greater degree in the Clypeastroida, and implies a considerable inclination of the lantern away from its typically vertical position in Regular Echinoidea.

The interradial ridges, feeble though their development is, have strong points of resemblance with the homologous structures of *Discoides* and *Conulus*, as I hope to show in a forthcoming paper.

It thus appears that the perignathic girdle of the Pygasteridæ shows a very close correspondence with that of phylogenetically or ontogenetically young Diademoida as regards the essential disposition of its elements; but that in its details it already indicates a progressive tendency towards the Clypeastroid type of girdle. The development of the short interradial buttresses, though clearly an adaptation to the requirements of the thin invaginated peristome, represents another foreshadowing of a typically Clypeastroid feature.

III.—Some Tertiary Dykes of the Clyde Area.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology, Glasgow University.

(*Concluded from the July Number, p. 315.*)

Leidleite and Inninmorite.—Typical rocks of these groups are as yet unknown in the Clyde area. A N.N.W. dyke at Barrassie Sands, near Troon (Ayrshire), has points in common with leidleite. It shows anorthite phenocrysts in a subvariolitic groundmass of acicular felspar and augite, enveloped in a partially devitrified glassy base. A north–south dyke at the north end of Loch Fad, Bute, may perhaps be regarded as a doleritic end-variety of leidleite (see Anderson & Radley, 1916, fig. 2*b*, p. 208). A pitchstone-like dyke from the Smurig Burn in the south of Arran has all the characters of leidleite, except that it carries rather abundant granular augite, instead of acicular crystals.

Tholeiite (Brunton Type).—This type has been based by the petrographers of the Geological Survey on the so-called "augite-andesite" of the Brunton dyke, Bingfield, Northumberland, figured by Harker (1908, fig. 54, p. 203), and described and figured by Teall (1884, pp. 236–7). It is abundant among the Tertiary dykes of Mull, and two analyses of the type have recently been recorded (Geological Survey, 1914, p. 82; 1915, p. 55). In the brief notes accompanying the analyses these rocks are said to be composed respectively of "small clots of augite and acicular crystals of plagioclase, with interstitial dark-brown glass", and of "augite, moderately basic plagioclase, magnetite, and of dark interstitial glass". Teall describes the microscopical character of the Brunton dyke as follows: "long, narrow, lath-shaped felspars, irregular crystalline grains and plates of a nearly colourless pyroxene, and a small quantity of nearly opaque interstitial matter." The rock is figured in pl. xii, fig. 6, of his paper. Judging from the figures given by Harker & Teall, and from thin sections of Brunton types from the North of England dykes in the collection of the Geological Department of Glasgow University, the felspar and augite are approximately equally developed, with perhaps a slight excess of the pyroxene, and the amount of glass is only slightly subordinate to either of the crystalline constituents. The Tynemouth dyke and several of the Ayrshire examples carry large phenocrysts of bytownite or anorthite of exactly the same characters as in cumbraite or inninmorite. Magnetite may or may not be present, and the texture is typically intersertal or tholeiitic. The type is clearly more basic than leidleite, inninmorite, or cumbraite, a fact reflected in the diminished quantity of glass. Norms calculated from the analyses of the Brunton type published by the Geological Survey show no quartz and 5 per cent of orthoclase in the 1914 analysis, and 4·2 per cent of quartz and 5·5 per cent of orthoclase in the 1915 analysis. Both rocks fall into the subrang *camptonose* (III, 5. 3. 4), showing at once that they are richer in the femic minerals than cumbraite, etc., and that there is only a negligible amount, if any, of excess silica.

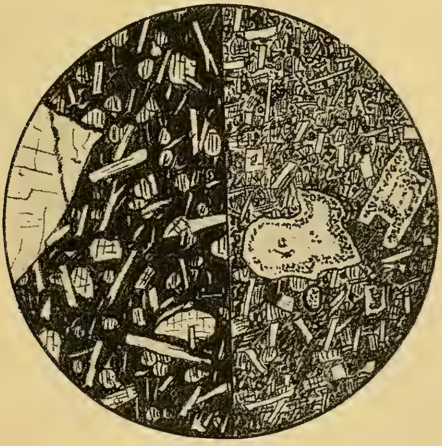
a  b

FIG. 2*a*.—Tholeiite (Brunton type), N.N.W. dyke, Stairaird, River Ayr, near Mauchline, Ayrshire. × 20. Large phenocryst of bytownite-anorthite; groundmass: grains of augite, and laths of labradorite, in base of dark glass.

,, 2*b*.—Olivine-tholeiite (Corrie type), N.N.W. dyke, Birchpoint, Corrie, Arran. × 20. Corroded phenocrysts of bytownite-anorthite; groundmass: laths of labradorite, grains of augite, olivine, and magnetite, in scanty base of dark glass.

The Ayrshire examples of the Brunton type of tholeiite may be represented by a N.N.W. dyke crossing the River Ayr near Stairaird, Mauchline. This rock (Fig. 2*a*) shows clusters of almost colourless granular augite, intermixed with diversely arranged, short felspar laths ($Ab_1 An_1$), all held in a black glass. The phenocrysts consist of bytownite-anorthite with a narrow rim of labradorite, exactly similar to those of cumbraite. A rough estimate of relative proportions is about 35 per cent each of the groundmass felspars and augite, 20 per cent glass, and 10 per cent of anorthite phenocrysts. A very small amount of olivine, fresh in this rock but serpentinized in the others, may be detected. On examination by a high-power objective the "black" glass turns out to be colourless, but charged with swarms of opaque black microlites. N.N.W. dykes conforming to this type, and exhibiting only minor variations in the quantitative relations of the minerals, occur in the River Ayr at Failford, near Tarbolton; in the Broadlie House Burn, near Dalry; and in the Coachford Burn, Cooperhill, Ochiltree.

Tholeiites of the Brunton type do not appear to be common in Arran, only three examples being known in a large suite of the Tertiary dykes. These dykes occur in the South Locherim Burn, Corrie; at 1,538 feet on the Saddle, between Glen Rosa and Glen Sannox; and on the shore near Largiemeanoch, Whiting Bay. Likewise Dr. W. R. Smellie's slides of the Tertiary dykes of Bute show only three examples belonging to the Brunton type, a dyke at the south end of Loch Fad; in the quarry behind the Power Station, Ardbeg, Rothesay; and on the shore south side of Stravannan Bay. Only one dyke of the Brunton type occurs in the Great Cumbrae, a north-west dyke, 11 feet thick, at Portachur Point.

Olivine Tholeiite.—These dykes appear to represent a further and more basic stage than those of the Brunton type, although preserving a sufficient community of character with the foregoing to warrant the view that they are a continuation of the same series. They are characterized by the presence, often an abundance, of fresh olivine, and by the presence of a glassy base in minimum quantity. No chemical analysis of this group has yet been made. Two types are recognized according to the relative abundance of olivine. The first type, characterized by a small quantity of olivine and by its restriction to the groundmass, is represented by a large group of dykes near Corrie, Arran, and may accordingly be known as olivine tholeiite of the Corrie type. A typical example is provided by a dyke at Birchpoint, on the shore south of Corrie. This rock (Fig. 2*b*) carries numerous small phenocrysts of bytownite-anorthite with narrow labradorite margins. These crystals are often worn and corroded into curiously irregular shapes, and have glassy inclusions arranged in a thick marginal zone which faithfully follows the fantastic outlines of the crystals. The groundmass consists of a diverse mesh of short laths of labradorite ($Ab_1 An_1$), intermixed with granular or short prismatic crystals of a pale, violet-brown augite which is the most abundant constituent of the groundmass. Minute grains of olivine, partially or wholly serpentinized, and of euhedral magnetite, are uniformly scattered over the field, but form minor constituents of the groundmass. The interstices are filled by a colourless glass, darkened by innumerable globulites. Quantitatively the glass forms probably less than 10 per cent of the total rock. Minute spherical vesicles filled with dark glass are rather abundant.[1]

Rocks of this type occur freely near Corrie, but have not yet been found elsewhere. They vary within small limits of quantitative relations and texture.

The second type may be known as the Largs type owing to the occurrence of two beautifully fresh dykes on the shore near the town of Largs, Ayrshire. An extended description of these rocks is unnecessary, as they differ from the Corrie type only in the much greater abundance of olivine, not only as granular constituents of the groundmass, but as large phenocrysts. In the groundmass (Fig. 3*a*) there is an augmented proportion of augite relative to the other constituents, and a diminished, almost vanishing, proportion of glassy base. A dyke of this character also occurs in the gorge known as Creag Bhan, Whiting Bay, Arran. This type may be regarded as the most basic of the tholeiitic series of Tertiary dykes.

FIG. 3*a*.—Olivine-tholeiite (Largs type), N.N.W. dyke, shore ¾ mile south of Pier, Largs, Ayrshire. × 20. Phenocrysts of anorthite and olivine; groundmass: laths of labradorite, grains of augite and olivine, in scanty base of dark glass. × 20.

,, 3*b*.—Crinanite, N.N.E. dyke, high road above Cordon, Lamlash, Arran. × 20. Ophitic plexus of titanaugite and labradorite laths, with abundant olivine and magnetite. Fresh, colourless analcite in triangular interstices between the felspars.

OPHITIC OLIVINE-DOLERITE AND CRINANITE (Fig. 3*b*).—The dykes of this group stand apart from those belonging to the tholeiite series, and, as far as present knowledge goes, appear to belong to an earlier phase of Tertiary volcanic activity in the Clyde area. A crinanite dyke from Whiting Bay, Arran, was described some years ago (Tyrrell, 1913); but a large number of these dykes have since been

[1] For a figure of this rock see Tyrrell, 1909, Pl. XIX, Fig. 5.

discovered all over the Clyde area. The true crinanites are inseparably associated with, and may be shown to pass into by a graduated series of sections, ophitic olivine-dolerites, which differ from them only in the absence of analcite or radial zeolites. The group is typically non-porphyritic, free from glass, and rich in olivine. In general the rocks are so fresh that it is difficult to believe that the interstitial analcite and zeolites can be other than primary constituents. The crinanites are ophitic olivine-analcite-dolerites of mafelsic composition, i.e. the felspars are quantitatively approximately equal to the combined olivine, augite, and iron-ores. The chemical analysis of a typical crinanite from Inver, Jura (Flett, 1911), gives a norm which falls into the subrang *auvergnose* of the American Quantitative Classification, but very close to *ornose* (III, 5 (3)4. ′5). It shows 1·5 per cent of nepheline, and consequently the rock falls into the "unsaturated" group of Shand, whereas the tholeiites are quartzose and fall into the "over-saturated" group.

A typical example from Whiting Bay is described in the above-cited paper. The felspar is much in excess of the augite, so that the small plates of the latter mineral are cut up into thin, detached, triangular strips by the felspar laths. The augite is always the deeply coloured, brown-violet, titaniferous variety. The olivine is generally quite fresh, and occurs in rounded grains which are uniformly distributed over the field. The interstices are filled with analcite or radial zeolites, but the amount is always small, much smaller than in the teschenite group. When the olivine happens to be serpentinized, the green material appears to migrate into the interstices and obscures the presence of analcite. Some of the dykes may thus be set down as olivine-dolerites when they are really crinanites. The rocks vary in coarseness of texture from almost gabbroid to basaltic types, according to the size of the intrusion. They usually occur as broad, massive dykes, which may in some cases have feeder relations to the great crinanite sills of the south of Arran. Besides the Whiting Bay dyke mentioned above, crinanites are now known to occur in Arran at the following places: Kingscross Burn, a quarter of a mile south-west of Kingscross Bridge; by the high road above Cordon, Lamlash (Fig. 3*b*); on the shore south-east of Cordon, Lamlash; the shore a quarter of a mile north of the Pier, Brodick; Invercloy, Brodick; and An Sgriob Quarry, 2 miles south of Corrie. Related olivine-dolerites occur at the first fall in Glen Ashdale, Whiting Bay, and on the shore near Dunfion, Corriegills.

In Bute a N.-S. crinanite dyke extraordinarily rich in fresh olivine occurs on the road 2 miles north-east of Dunstrone; and a 3 ft. N.N.E. dyke on the shore at Kerrytonlia is probably also a crinanite, but contains much diffused serpentinous matter. The related olivine-dolerites also appear in several places. In the great Cumbrae two crinanite dykes are known, and two of the related olivine-dolerites (Tyrrell, 1917). Both here and in Bute the dykes of this group trend in a N. to S. or N.N.E. direction. On the Ayrshire mainland crinanites are known from the shore near the Heads of Ayr.

Conclusion. — Although much still remains to be discovered concerning the thousands of Tertiary dykes in the Clyde area it is already clear that they show considerable petrographic diversity, and that the various groups have differing relations in regard to their size, length, direction, age, and degree of connexion with the local centres of Tertiary volcanic activity. Only rocks of andesitic or basaltic composition have been dealt with in this paper. There is a well-marked division into two groups: (*a*) a tholeiitic group, characterized by the presence of glass, intersertal texture, phenocrysts of basic felspar, and presence of occult quartz; and (*b*) a crinanite–olivine-dolerite group, with coarse ophitic texture, with interstitial analcite or radial zeolites, rich in olivine, and free from glass or phenocrysts. The tholeiitic group ranges in chemical composition from sub-acid types (Anderson & Radley, 1916, p. 210) to thoroughly basic types such as those of Corrie and Largs. The crinanite–olivine-dolerite group, however, shows no significant variation, and remains uniformly basic. It is probable that other groups will be found as investigation proceeds, especially in Arran, where only a tithe of the dykes (and related sills) have been closely examined. It will be necessary in future to define the relation, if any, between the great pitchstone-felsite group of Arran and the tholeiitic series. There may also be a relation between the crinanites and the basalt-felsite composite sills and dykes of the south of Arran.

I must acknowledge with gratitude the assistance received in this work from Dr. H. H. Thomas, Petrographer to the Geological Survey, who has not only loaned to me all the Survey slides bearing on the subject, but has looked through many of my slides and compared the rocks with the types occurring in Mull. I am also much indebted to Mr. Chetai Yu and Dr. Alex. Scott for the excellent chemical analysis of cumbraite in this paper.

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IV.—OBSERVATIONS ON THE RECONSTRUCTED SKELETON OF THE DINOSAURIAN REPTILE *DIPLODOCUS CARNEGIEI* AS SET UP BY DR. W. J. HOLLAND IN THE NATURAL HISTORY MUSEUM IN LONDON, AND AN ATTEMPT TO RESTORE IT BY MEANS OF A MODEL.

(PLATES XXII AND XXIII.)

By the Rev. H. N. HUTCHINSON, M.A., F.R.G.S., F.G.S., F.Z.S., etc.

IN the following pages the writer has endeavoured to consider this skeleton in a common-sense way, and to arrange the limbs with reference to ordinary mechanical principles, and also by comparison of the bones with those of different mammalian and reptilian types. A good many years ago, Von Meyer was so struck by the colossal and rather straight hind-limb bones of the Dinosauria and their superficial resemblance to those of elephants, that he proposed the term Elephantopoda; but at that time the group had not been classified by Marsh and others into distinct sub-orders, with very different limbs.

The writer maintains that Dr. W. J. Holland,[1] Professor Osborn,[2] Dr. Marsh, Hatcher,[3] and others who are responsible for the present reconstruction (see Plate XXII) have been, perhaps unconsciously, influenced by Von Meyer's interpretation, and consequently were somewhat too anxious to produce something very big and imposing. He has endeavoured to give a more natural interpretation of this skeleton, and to bring it more into harmony with other types of reptiles. The restorations by Tornier and Holland are given in the *American Naturalist*, vol. xliv, 1910.

Before proceeding to discuss the details of this colossal skeleton, 81 feet long or more, it will be convenient briefly to summarize the broad conclusions which have been arrived at.

1. With regard to the general pose of the skeleton. There are grave reasons for considering that it stands too high.

2. The limbs, instead of being placed in a vertical plane, should be inclined at an angle to the body, somewhat as we see in lizards and crocodiles. Such an arrangement involves bringing down the vertebral column into a lower position, such that the

[1] W. J. Holland, Memoirs of the Carnegie Museum, vol. ii, No. 6, *The Osteology of Diplodocus, Marsh.*

[2] "A Review of some recent criticisms of the restorations of Sauropod Dinosaurs existing in the Museums of the United States, with special reference to that of *Diplodocus Carnegiei* in the Carnegie Museum": *American Naturalist*, vol. xliv, May, 1910.

[3] Dr. J. B. Hatcher, Memoirs of the Carnegie Museum, vols. i and ii.

Model of the skeleton of *DIPLODOCUS CARNEGIEI*, set up under direction of Dr. W. J. Holland, of the Carnegie Museum, Pittsburgh, Pennsylvania, U.S., in the British Museum (Natural History).

abdominal surface will rest not very far above the ground. The writer has constructed a model 4 feet long in plasticine. Plate XXIII is from a photograph of a plaster cast from this model, which may now be seen in the British Museum (Natural History), Cromwell Road, S.W. It is in the Reptile Room and under the *Diplodocus* Skeleton.

3. That *Diplodocus* was, in habit, partly aquatic and partly terrestrial.

From Plate XXIII the reader will see the position that has been chosen for this restoration. The tail mostly rests on the ground and the body is horizontal, while the long neck has a slight and graceful curve upward. A long, narrow ridge is shown on the back, which gradually rises upward from the shoulders to the lumbar region. The writer thinks he is justified in making this ridge, because a ridge exists in many recent reptilian types, though of course such appendages depend largely upon climate, etc. Lizards inhabiting sandy deserts show a profusion of spines, scales, etc., which evidently are protective. Even plants show a similar tendency to avoid the chances of being devoured by hungry mammals. But we must not assume such conditions existed, and so have dispensed with all appendages of that kind.

The limbs should be quite free from the body; and any attempt to place the femur within the body of *Diplodocus* as if it were a mammal would be a fatal mistake. Dr. W. J. Holland has ventured to do so (see his restored skeleton in the Natural History Museum and Plate XXII).

But such interpretation is not borne out by the shape and general plan of the femur. The writer contends that to place the limb bones in an upright position, as in the skeleton now under consideration (and in the restorations of Marsh, Hatcher, Osborn, and others), is not consistent with the position of *Diplodocus* in the animal kingdom. For, after all, it is a reptile. There is no getting away from that fact: and therefore we must beware of the temptation to give any appearance of usurping characters that properly belong to the mammalian class. But on the other hand, to say that it is a reptile does not necessarily imply a belief that it crawled low down like a lizard or a crocodile. The somewhat grotesque arrangement of the skeleton shown in Dr. Tornier's restoration is based on that view, and the result is obviously an impossible interpretation. Nor can the writer see his way to accept the view that *Diplodocus* walked in the sense in which we apply that expression as to the mode of progression seen in big mammals such as the elephant and rhinoceros.

According to Von Zittel, the Sauropoda display closer relationships with Crocodilians than do the other orders of Dinosaurs, and share a number of features in common with the Parasuchia (*Belodon*, etc.). This important conclusion by such an authority must be borne in mind in considering *Diplodocus*. Hence the writer feels justified in dealing with the femur of *Diplodocus*, largely by comparison with that of the crocodile.

We must try to picture something between crawling and walking, as expressed by our restored model. The relatively small size of the pelvic girdle is, of itself, enough to remind us that, in trying to form a mental picture of *Diplodocus* as it lived, we must constantly bear in mind that it belongs to a rather generalized sub-order of the Dinosauria, and that among recent reptiles the Crocodile is the nearest thing to it.

With regard to the extremities of the limbs, the hind foot and manus have been given positions which may be described as plantigrade on the whole, but not so much so as the crocodile or the lizard.

The photograph of the model seen in Plate XXIII will serve to show that the writer has endeavoured to steer a middle course between the extreme view of Dr. J. B. Hatcher on the one hand and Dr. Tornier on the other (see Fig. 2).

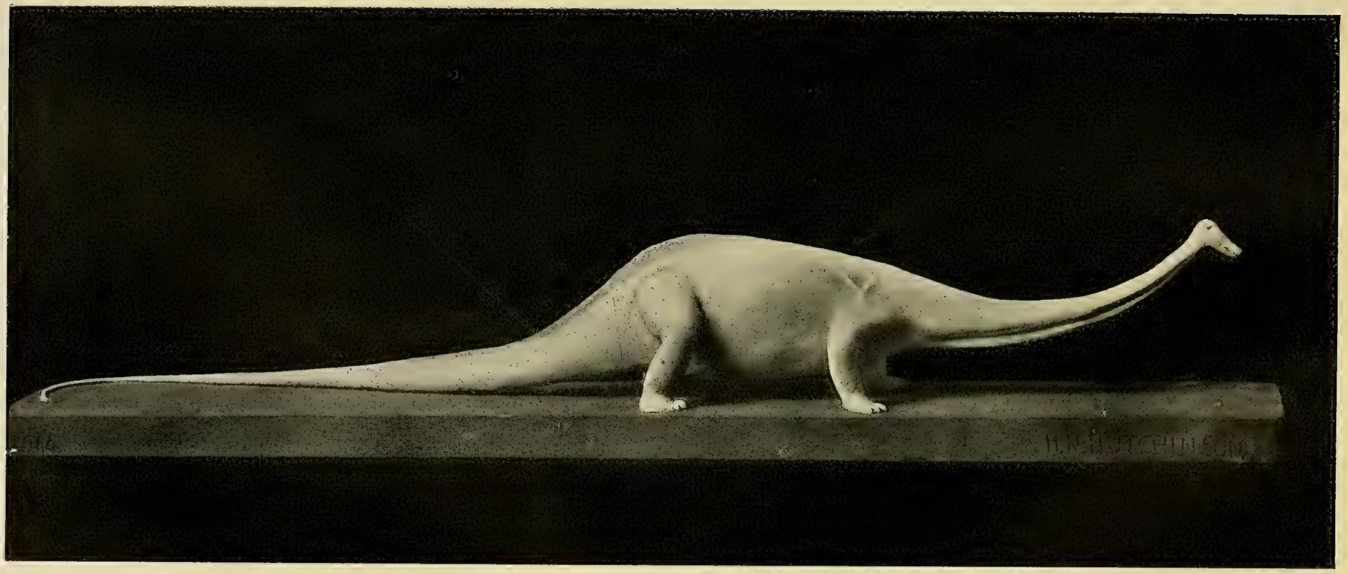
Habits.

With regard to the habits of this creature, there have been great differences of opinion. The late Dr. J. B. Hatcher, whose valuable papers on this subject the writer has read with great interest, was at first inclined to believe that *Diplodocus* was an aquatic reptile, but subsequently he somewhat modified his views, and in his latest paper (Memoirs of the Carnegie Museum, vol. ii) he gives reasons for thinking that the habits of the creature were mainly terrestrial. The present writer is not inclined to adopt this view, but considers that *Diplodocus* spent much time in the waters of the rivers and lakes in those far-off Jurassic times.

To take one reason only, it is difficult to imagine this great creature supporting such a long neck and a still longer tail on dry ground. When standing up the strain of supporting so much weight might become too excessive, but by taking to the water and resting there such strain would be greatly relieved. Perhaps the shape of the jaws and of the proximal end of the skull, which is decidedly duck-like, helps to confirm this view. The swan has a long neck, but gets over the difficulty by keeping it upright. This no doubt suggested the attitude given in Dr. Tornier's restoration of the skeleton.

At first sight *Diplodocus* might possibly appear a somewhat defenceless kind of animal, but judging from the habits of certain living reptiles, such as the monitors, one may safely conclude that this long tail was used very effectively as a whip whereby to lash its enemies. Its great length is remarkable. The long neck doubtless made a long tail desirable, otherwise *Diplodocus* could not succeed in hitting an enemy trying to attack its head.

Professor H. F. Osborn in his paper on "A Skeleton of *Diplodocus*" (on p. 14) leans to the view that *Diplodocus* was of aquatic habits, holding that the tail was especially modified to function as a swimming organ, and was provided distally with a vertical fin. He believes the chief function of the tail to have been that of a propeller to aid the animal in swimming, and that it functioned secondarily as a balancing and supporting organ. While holding that the Sauropoda are aquatic and quadrupedal, he infers that they were capable of migration on land and assuming both a bipedal and tripodal position, the tail when in the latter position functioning as a third support in conjunction with the hinder pair of legs.



Photograph of Model of *DIPLODOCUS CARNEGIEI*, as restored by the Rev. H. N. Hutchinson, M.A., F.G.S., F.Z.S.

It may be worth while briefly to indicate the views put forward by Dr. J. B. Hatcher, O. C. Marsh, and Professor H. F. Osborn. As Hatcher points out in his valuable paper above referred to, Marsh was the first to advance the aquatic habits of *Diplodocus*, having considered the position of the narial openings (nostrils) quite on the top of the skull, as suggestive of such habits. But this conclusion, some authorities think, is more or less shaken by the fact that certain mammals show rather similar conditions without being aquatic. Again, in dealing with the skeleton of *Cetiosaurus*, he lays stress on the open cancellous tissue of the vertebræ and limbs. At the time it was thought that they showed no trace of any medullary cavity. But more recent researches have shown that some of the Sauropoda *had* a medullary cavity. Dr. Hatcher thought that, if modified at all for aquatic habits, it was in the direction of more open and cancellous tissue, even than that which obtains in the Cetacea, and calculated not only to give greater buoyancy to these massive quadrupeds when in the water, but in addition to give the greatest possible surface for muscular attachment compatible with the required rigidity and with the least possible weight.

In the same paper Hatcher sums up his conclusions with regard to the locomotive powers of *Diplodocus* in the following words: "That the movements of the animal when on land were decidedly slow and clumsy; for, had *Diplodocus* and its ancestors been addicted to terrestrial life, the habitual support of so massive a body in so light a medium as the atmosphere would scarcely have failed to produce closely applied and well-finished articular surfaces to the limb-bones similar to those which obtain in such members of the Theropoda as are of undoubted terrestrial habits."

In his second paper (Mem. Carnegie Inst., vol. ii, p. 58) Hatcher revises his previous conclusions. He disagrees with Osborn's conclusion about a tail-fin. The limbs, he thought, were essentially terrestrial. They are not abbreviated or subordinated, as in the Amphibia and Reptilia and some aquatic Mammals. So he thinks the limbs were first of all ambulatory to give support to the body. He also believes his conclusions to be strengthened by a study of the fossil remains found with *Diplodocus* and the nature of the rocks in which they occur, viz. sandstones. Thus we see how the various authorities differ among themselves. One more argument may be mentioned here. He refers to the deeply pitted articular surfaces of the various parts of the appendicular skeleton (i.e. the four limbs and the pectoral and pelvic girdles). These, he thinks, may mean that there were thick cartilaginous pads interposed between such surfaces at the various joints of the limbs and feet. This want of closely-fitting and well-defined articular surfaces would appear to afford additional evidence of aquatic habits. Here the writer would like to point out that an animal may be very largely aquatic in habit without showing much trace of such habit in its skeleton. For instance, the hippopotamus, the water-rat, water-hog, otter, polar bear, and crocodile are largely aquatic, and yet if known only by fossil remains, would be put down as entirely terrestrial! One has to be cautious in drawing conclusions. American naturalists have pointed out the compressed shape of the body, like that of a herring, as confirming the evidence of aquatic habits (see Fig. 1).

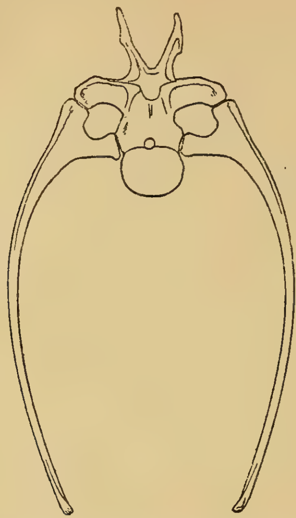


FIG. 1.—Ribs of *Diplodocus* in position.

HISTORY OF THE SKELETON.

We must now consider the skeleton in detail. In dealing with this skeleton, it must be remembered that we have before us not the actual skeleton, but a reconstruction thereof. Each bone, as we see it, is a cast made from a model, and these models are based on several finds of *Diplodocus* made at different times by Marsh, Osborn, Holland, and others.

MATERIALS FOR THE RECONSTRUCTED SKELETON.

Before we proceed to discuss this reconstructed skeleton, it will be convenient to indicate very briefly the nature of the fossilized material on which it is based. Dr. J. B. Hatcher explains in his two valuable papers, (1) Mem. Carnegie Museum, vol. i, p. 4, (2) Mem. Carnegie Museum, vol. ii, p. 58, that his illustration of the skeleton, as far as he knew it then, was based on two skeletons neither of which was complete: (1) that known as No. 84, collected by Dr. J. L. Wortman in the expedition of 1899, and (2) another collected by D. A. Peterson in the expedition of 1900, in the same quarry in Sheep Creek in Albany, County Wyoming.

From a paper by Dr. W. J. Holland (Mem. Carnegie Museum, vol. ii, p. 225), we learn that since Dr. Hatcher's papers were published two other imperfect skeletons have been found. Apparently the skeleton set up in London may be taken in a general way to correspond with the drawing in Dr. W. J. Holland's memoir already referred to.

With regard to skulls of *Diplodocus*, Marsh had only two. The Carnegie Museum has a skull, but no complete skull is yet known. We have to be content with the photographs, etc., in the paper by Dr. W. J. Holland already referred to. The restored skull in the reconstructed skeleton in the Natural History Museum is based on these two skulls, but it probably will be modified when other specimens are discovered. The vertebral formula seems to be:—Cervicals 15, dorsals 11, sacrals 4 (or 5), caudals 35 (or 34).

The Posterior Limbs.

We must pass on now to consider the hind-limbs. Let us take, for example, the elephant, and see how its limbs work, comparing it with a lizard, such as *Varanus*. In *Elephas* the femur works up and down in a plane practically parallel with the axis of the body. In consequence a clear space is left for it by the late dorsal ribs, for they rapidly get shorter about midway in the region between the pectoral and the pelvic girdles. Also this enables the elephant to sit down with its hind-limbs tucked away as a horse does. Now *Diplodocus* could not have done this. Fig. 3 (p. 362) shows the

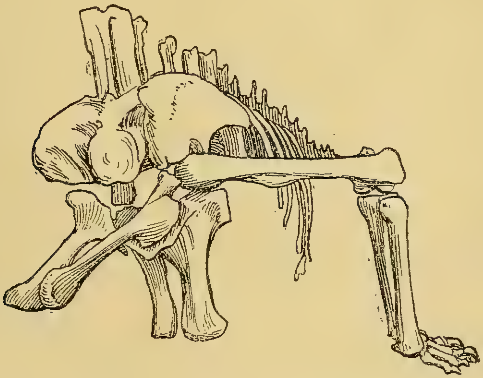


Fig. 2.—Posterior aspect of the pelvis and hind-limb of *Diplodocus* (after Tornier).

position of the hind-limb proposed by the writer. In the case of *Varanus*, a lizard, we perceive something quite different; there is not the same clear space for the movements of the femur, for the obvious reason that the femur of the reptile, instead of working up and down in nearly a vertical plane, works in a plane more or less horizontal, which may be compared to the movements of an oar in a rowing boat, while the others might be compared to a pendulum, which swings in a vertical plane. The ribs are shortened only when quite near to the pelvic girdle. The proximal portion of the *Diplodocus* hind-limb evidently was massive, to say the least, and the writer in his restoration (Plate XXIII) has made it fairly big. It may therefore well be asked how can room be found for this mass of flesh attached to the femur and ilium except by putting the limb at an angle with the body. Again, one feels justified in asking what evidence exists to show that the last two ribs were really as short as those seen in the diagram. Is it not possible that they are only based on guesswork, and made to harmonize with the general conception expressed by the reconstruction ?

FIG. 3.—Hind-limb of *Diplodocus* (after author).

The Femur.—Drawings of the femur of *Diplodocus* are given in Fig. 4. Let us examine these carefully, for it is largely from the

FIG. 4.—Two views of left femur of *Diplodocus*.

nature of this bone that the writer draws some of his chief conclusions. The first point to which we must direct attention is that the head of the femur is very poorly developed, as in the crocodile. Indeed, the femur as a whole is very crocodilian — a fact which some writers seem inclined to ignore. This imperfect head offers confirmation of the writer's view with regard to the arrangement of the hind-limbs. For it seems rather obvious that, if these limbs were intended to be upright and for walking in the manner of an elephant or other large mammal, then we should find this head of the femur much more fully developed—that is, rounder, larger, and more distinct altogether. As it is we see a mere bulging out on one side of the proximal end. How different this to the mammalian femur! But to come back to the Dinosauria, even the huge *Stegosaurus* has a more developed head to the femur. And there is good reason to conclude that this creature used its hind-limbs for walking rather than for crawling, and that they were set at a slight angle to the long axis of the body, as in birds. Again, *Triceratops* (von Zittel, *Palæontology*, ii, p. 243, Engl. ed.) confirms our view; for its femur shows quite a well-formed head, and this Dinosaur was much inclined to a quadrupedal gait. The writer ventures to think that the femur of *Diplodocus* shows a distinct advance upon that seen in *Varanus* or *Crocodilus*. We see the head asserting as it were a kind of individuality. It projects distinctly from the shaft, though only to a slight extent. We might almost be allowed to believe that here Nature was dimly groping after the more perfect types that we see in the Mammalia. We can well believe that this was one reason which led Hatcher and others to place the hind-limb nearly vertical. It is of course most essential that we should know the *true shape* of this bone as well as others. Now the femur we are dealing with is not the actual bone itself, but a reconstruction. The only way to be sure in these matters is to go to the actual fossil bones and see and judge for ourselves what their shapes may be. For this purpose one must go to the Fossil Reptile Gallery of our Natural History Museum. There we see bones and casts of bones of the Sauropoda. There is a femur of *Diplodocus*. It is a good deal crushed, especially at one end. One can compare it with the corresponding bone of *Brontosaurus*, *Cetiosaurus*, and the colossal *Atlantosaurus*. The writer was greatly interested to find that the bone is *distinctly curved* (see Fig. 4*b*). It has a double curvature. This is a very important fact, the meaning of which must be carefully borne in mind when one is attempting to make a restoration of *Diplodocus*. It brings us back to the crocodile, and reminds us that we are far away from the mammalian type. To place such a bone in a nearly vertical plane and so imply that *Diplodocus* was a kind of saurian elephant must be wrong from a mechanical point of view, as well as anatomically! In birds, and in mammals, the head of the femur is well developed; and the acetabulum is so shaped as to conform to this neat spherical head, forming an admirable ball-and-socket joint, a device well-known to the engineer, and well exhibited in man and in birds. But among reptiles this feature is usually absent, being only known among the Chelonia. The femur of the tortoise (or turtle), however, shows only an imperfect kind of head, not nearly a complete sphere. So with the humerus. Tortoises are highly specialized reptiles; and this contrivance is doubtless a very necessary one on account of the weight of the carapace, for without it the limbs could not perform their proper functions.

Dr. W. J. Holland and some others have been so bold as to place the femur right inside the creature's body, and in that way we presume they attempt to get out of the difficulty above referred to. But the result is certainly strange, causing *Diplodocus* to remind one of a cow rather than a reptile! (see Dr. Holland's model above referred to). Besides, the whole shape of the pelvic girdle militates against any such interpretation. If the femur really worked in the way suggested by Holland and others, the writer believes that a different shape of ilium would be necessary, viz. one more on the lines of a mammal, that is, more outspreading.

It is very instructive to compare the hind-limb of *Diplodocus* and *Triceratops*. Fortunately both these colossal Dinosaurs are exhibited in the same gallery at the Natural History Museum. Consequently the comparison is easily and rapidly made. Now the hind-limb of *Triceratops* (see the writer's *Extinct Monsters* and *Creatures of Other Days*, now in one vol., 1911, p. 182), owing to its rather upright position, and the ponderous nature of this Dinosaur (which probably possessed a heavy dermal armour, at least in the writer's opinion), had to support a great weight. Hence the three ungual phalanges are decidedly broad—more so than in any other known Dinosaur.[1] And, moreover, that outward twist, so noticeable in *Diplodocus*, is entirely absent. These and other features confirm a suggestion of the writer that *Triceratops* may claim to be regarded as a reptile that years ago played the part of a rhinoceros, i.e. foreshadowing in an imperfect reptilian way that great and ferocious mammal! The rather sharp and distinctly claw-like ungual phalanges of *Diplodocus* bear their testimony in favour of the interpretation of the skeleton adopted in this paper; for with the hind-limbs set up in the vertical plane (as in the American reconstruction) (Pl. XXII), the downward pressure brought to bear upon them would be so excessive that they would probably break, or if not, they would be pressed so deep into sand or soft earth as greatly to hinder progression on land. By way of illustration, and to show that this conclusion is based on reasonable grounds, let us take the case of a large dog, say a mastiff. Leave his limbs almost as they are, but give him a heavy body with a great massive vertebra and a long weighty tail; and then endeavour to picture his distress in propelling along the ground this mass of bone and flesh (even allowing for certain corresponding increase in strength of limb)! The weight of his body would be felt as direct downward pressure through the limbs and on to the toes. But place the limbs at an angle to the body, and this great pressure is relieved, because the femur—with the tibia and fibula, with the muscles attached to them—act as a kind of spring, set sideways to the body (see Fig. 3, p. 362).

[1] Compare with foot of *Elephas*.

The Tail.

The writer is convinced that no animal with such a tail as *Diplodocus* possessed could possibly walk along on terra firma with its huge body high above the ground and limbs erect, as in the elephant. And yet such a fact is implied by the skeleton now under consideration. By way of homely illustration, let us try to picture a big Monitor lizard set up on stilts as it were, by giving it long straight limbs, and made to walk with its heavy tail at such an angle as this great *Diplodocus* tail makes with the hind-quarters. Imagination fails! The pull of such a mass of flesh as belongs to the anterior caudal vertebræ would be prodigious! These vertebræ would require to be greatly strengthened by ossified tendons, as in *Iguanodon*. But even there the pull of the tail was lessened by the comparative lightness of the vertebræ.

In all these matters the law of correlation is a useful guide, though we admit by no means an infallible one. In a case like this it seems quite reasonable to make use of this guide, as Cuvier did who first propounded it. Looking at mammalian skeletons generally, we seem to discover that big upright limbs and a proper quadrupedal progression are correlated with small, light tails, as in *Elephas*, *Bos*, etc. Why is this? The answer seems to be, first, that the drag of a heavy tail would be too great, and secondly, that the limbs are designed for rapid movement. Let us inquire whether such a deduction is confirmed by any extinct reptile.

We return once more to the Dinosaur, which more than any other approaches the heavy type of herbivorous mammals; and that is the very remarkable *Triceratops* which bears out in a wonderful way Cuvier's prophetic vision of a "great herbivorous reptile" as applied to the famous *Iguanodon*. A glance at the model skeleton at South Kensington with its huge hind-limbs shows that, instead of making an angle with the body, they moved up and down in a vertical plane, as in *Elephas*, *Bos*, etc., or a very nearly vertical one. So here we actually have before us a reptile walking, as far as the hind-limbs are concerned, after the manner of an ox! Its toes point forwards; and it evidently walked in true quadrupedal fashion, though perhaps they may have had a slight inclination outwards, as in birds. And what about its tail? The tail is comparatively light and slender, and quite unlike that of any other Dinosaur. And so our argument is confirmed; *Diplodocus* never had its femur working in a plane parallel to axis of the body as in mammals.

Discovery of a yet Greater Reptile.

Some five or six years ago, news was received of the discovery in German East Africa of Dinosaurian bones, of the sub-order Sauropoda, exceeding in length anything yet known even in the Western States. Wonders never cease in the domain of palæontology. Here were bones of such colossal dimensions as would have fairly staggered even the late Professor Marsh! North America no longer can claim the biggest reptile that ever walked the earth. East Africa takes the palm. For here are bones which afford a basis of comparison of relative sizes, and one authority has ventured to estimate the length of this new reptile, *Gigantosaurus* by name, at 150 feet! This discovery, we think, tends to confirm the above argument with regard to *Diplodocus*, its tail and its general pose; for the larger the reptile the greater the pull of its tail on the pelvic region, to say nothing of the strain on the legs. Besides, mathematicians now tell us plainly that there are certain physical limitations to the size of a terrestrial animal (see recent discussions in *Nature*).

By articulating limbs vertically, Hatcher and others have made a kind of mongrel animal, part reptile, part mammal. *Nature does not mix her types*; so *Diplodocus must* be either reptilian or mammalian; it cannot be both. Its upright limbs are an anomaly. Mammals are swifter of foot than reptiles. The mammalian skeleton is constructed for speed, and is in every way adapted for upright limbs. The pectoral and pelvic girdles are adapted to such limbs. This is seen most conspicuously in the humerus and the femur.

Articulation of the Vertebral Column.

A few years ago the writer, in a visit to the Berlin Natur-Kund Museum, had the opportunity of discussing the *Diplodocus* skeleton with Dr. Brauer of that Museum. He is among those who do not accept the interpretation of *Diplodocus* as represented by the skeleton in London. And with regard to the tail, he brought forward an argument which, as far as the writer is aware, has not been satisfactorily answered. It is this: that several of the early caudal vertebræ have been forced into unnatural positions, as shown by the curious angular gaps between them. This can be distinctly seen in the London specimen. But in the restored skeleton of Dr. W. J. Holland's Memoir on the Osteology of *Diplodocus*, Marsh (Memoirs Carnegie Museum, vol. ii, No. 6), there is no sign of this want of harmony in the arrangement of the caudal vertebræ.

The present writer has also noticed that a good many of the vertebræ a little below those just spoken of show an entire want of contact between the surfaces of the pre- and post-zygapophyses. One would think that facts such as these might be sufficient in the minds of unprejudiced naturalists to settle the question of the slope of the tail, etc. But no! the American palæontologists wished this great reptile to be as tall as they could make it. It has been shrewdly pointed out by Professor S. W. Williston of Chicago, that in *Diplodocus*, as set up in our Natural History Museum, the position of the tail is such as to make the extrusion of an egg an impossibility! It is not easy to conjecture what answer will be made to this objection by other Transatlantic naturalists.

Supposing, as is likely, that *Diplodocus* was partly aquatic in habit and sought his food in the waters of rivers and lakes, one can well imagine that such a long tail would be useful by way of balancing the body, and especially so if at times the body was raised up to bring the head and neck up to the surface of the waters for respiration. Professor H. F. Osborn put forward this view in 1899 (*Science*, n.s., vol. x, No. 259, pp. 870–4, December 15, 1899).

But he evidently stretches this view too far in the sketch of a model of *Diplodocus* standing on its hind-legs, published in the

Century Magazine, September, 1904. In the former one can see clearly that Professor Osborn has disregarded the true proportions of *Diplodocus*, making the neck far too long, the fore-limbs too small, and giving it a very weak chest!

The Carpal and Tarsal Bones.

If *Diplodocus* walked as a mammal, then we can only say that its walking must have been of a very inefficient character. Have the American naturalists ever considered this point—that *Diplodocus* seems to possess very few wrist and ankle bones? They were evidently largely encased in cartilage, as in living reptiles and in all the early amphibians and reptiles. *This, we maintain, renders it quite impossible for the animal in question to have walked like an elephant.* More bones would be required in the joints to give the necessary strength to bear so great a weight, and also to render them sufficiently flexible their surfaces would not have been so flat. On comparing the carpals and tarsals with those of living reptiles, the writer finds that they approach more nearly to those of the Brazilian tortoise than to anything else. In the hind-limb there is the same fusion of several bones into one, thus forming a single bone which probably consisted of the fibiale, intermedium, centrale, and tibiale; in the carpus, we seem to have the radiale and centrale combined and perhaps the intermedium. Now, if these bones so much resemble the corresponding bones of a tortoise, is it not allowable and reasonable to argue that the limbs were used in the same manner, and especially that the joints were not subjected to such extensive or so frequent flexure as in the case of an elephant? Consider how widely the mode of progression of a tortoise differs from that of a mammal. The former slowly drags the limb round much as an oarsman might slowly bring his oar forward for the next stroke, while the elephant quickly brings it forward much as a man brings his leg up for the next stride, and in so doing he bends the tarsal bones in a way that is not possible to any reptile.

But, after all, the writer would urge that perhaps the best evidence for the view here maintained is to be found in the nature of the pelvic girdle. It is beyond all doubt crocodilian, and well adapted to hold the kind of muscles required to work the hind-leg sideways like the oar of a boat. It certainly does not possess that arching-over shape necessary in the case of an animal that uses its hind-leg for movements up and down like a pendulum (see p. 362, Fig. 3). There simply is no room for the big muscles that would be required for that kind of movement.

The Fore-limbs. (Figs. 5–7.)

The writer has long maintained that the worst of all mistakes made in the setting up of the skeleton now under consideration is the way in which the *fore-limbs* are set up. It is hardly too much to say that, in the whole animal kingdom, there is not to be found any limb arranged in such a weird manner as this! Taking a side view of the skeleton, one sees with positive amazement that the bones make an *inward* curve, like a bow set up, so that its convex side points towards the posterior end of the animal. Fig. 5 shows the articulation proposed by the writer.

The position of the fore-limb is mechanically impossible! Such a bow would collapse under the strain put upon it.

It is important to bear in mind that this curvature is all in one plane, a vertical plane. There is no foreshortening or any bulging out at an angle to the body as in modern reptiles. Now this must be wrong. We will return to this matter later on. It is difficult, one might almost say impossible, to conceive that such a bone was intended to be used for movements in a direction *AB* and *CD* parallel with the major axis of the skeleton, as in mammals, as indicated in the diagram Fig. 8, p. 369.

5 6 7

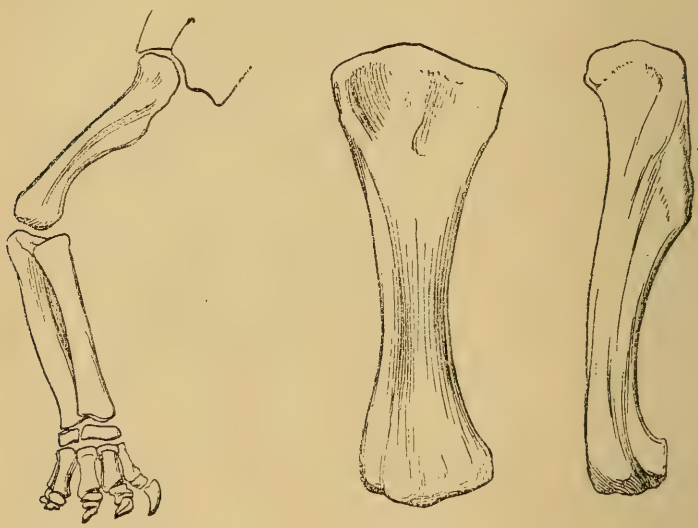
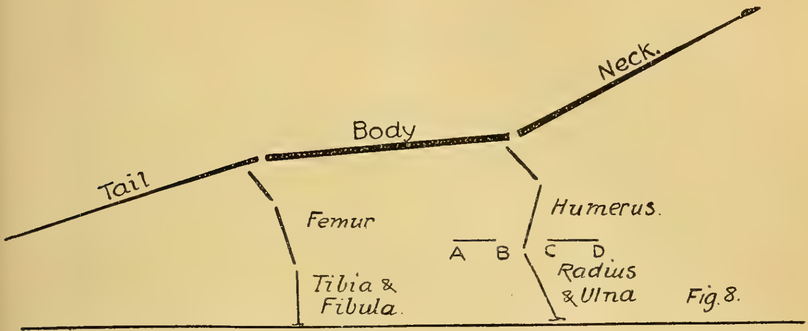


Fig. 5, fore-limb (after author); Figs. 6, 7, two views of humerus of *Diplodocus*.

As already pointed out, that inward curve of the humerus makes it weak. Hatcher put it the other way about. But no bone intended to work in such a manner would be so thin in the direction at right angles to its movements. They are always thick in the direction in which they are used. It must be wrong mechanically. Compare the humerus of a dog, or rhinoceros, elephant, etc. They all have a rounder shape which gives them the necessary strength for movements in the directions *AB* and *CD* in a vertical plane, or, in other words, in directions at right angles to its major axis. Now this is just the direction in which the humerus is thinnest.

Now compare this arrangement with the posture adopted in our restoration. The humerus now works something like an oar. Fig. 9

shows how on the reptilian plan the movements of humerus would follow the arc *ABC*, and in this way the great breadth of this bone would make it thick, or deep, just in the direction where strength is required. Again, that broad spatulate end shown in Fig. 21 is really another argument in the same direction. Looked at from a mechanical point of view, it speaks volumes. Why should it have that large rounded end unless its surface moved more or less in an arc and attached rather loosely to this concavity? Moreover, the glenoid cavity, although not very well preserved, seems to exhibit a shape more or less corresponding with such an outline (Figs. 20–3). The crocodile's humerus is useful for comparison.



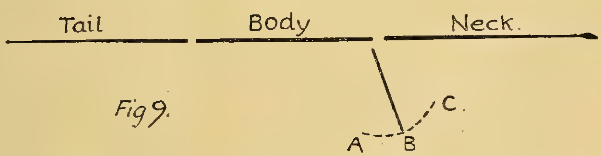


FIG. 8.—Diagram to illustrate wrong articulation of the limb-bones of the *Diplodocus* skeleton. The body, neck, and tail are shortened for convenience.
FIG. 9.—Diagram showing working of humerus of *Diplodocus* (ground-plan).

As mounted, this broad, spoon-shaped blade (see Fig. 6) is placed directly at right angles to the scapula and general direction of the glenoid cavity. Is it likely the big muscles attached to this broad scapula could suddenly change their direction, and somehow twist themselves on to the humerus? They would have to pass over a long and rather sharp ridge. And, moreover, the surface of contact is so small as to suggest a mere point of contact and not a proper broad surface. Such a condition is absurd and unthinkable. Bear in mind that owing to the great weight of *Diplodocus* the pressure on this ridge would be tremendous. The muscles would be lacerated and after a time actually severed. But on the other hand, by turning humerus round 90 degrees we get a suitable broad surface to which the muscles can be attached without violently changing their direction.

This can best be illustrated by means of a pocket-handkerchief. Place it on an extended left arm, with part hanging over one side near the body. Then put the right hand under it with the fingers placed at right angles to the arm. They project in a sharp edge. Now turn the hand round through 90 degrees of arc, and this awkward projecting edge vanishes. It is most instructive to compare with this the articulation seen in *Nesiosaurus*, *Pareiasaurus*, *Iguanodon*, *Thescelosaurus*, and many other forms. They all confirm the idea of an oar, rather than a pendulum (see p. 369, Fig. 9, A, B, C).

The writer has consulted on this point a London University Professor of Engineering, who confirms the views here expressed.

Physiology a Useful Guide.

To all students of evolution it is important to bear in mind, as a guiding principle, the one which Sir Richard Owen always kept steadily in view, that anatomy and physiology go hand in hand. There is a kind of correlation between them. The evolutionist, in pondering over the development of animal life on the earth from the earliest geologic periods to the present day, perceives on reflection that every great advance in structure is based not only on anatomical improvements but also on physiological changes. Thus, the mammal takes the place of the reptile in the order of evolution, and exhibits a heart with four chambers, compared with the reptiles' three; and the reason for this is that the mammal is intended to win a higher place for himself. He must be stronger and swifter, and more intelligent than the reptile. His limbs are therefore stronger, and his brain more active. Hence he requires an improved apparatus. Nature, the great designer, acts in much the same way as an engineer. It is as if an engineer had to deal with an old out-of-date motor-car. He wants to improve it and make it run better and faster. So he takes out the old three-cylinder engine and replaces it by one with four cylinders. He also strengthens the chassis here and there, and thus obtains the results that have been slowly arrived at. So nature discarded the old reptilian heart and replaced it by one of greater power to pump the blood to all parts of the body.

Although land mammals differ very much among themselves as regards powers of progression, they are on the whole better endowed for this purpose than either the amphibia or reptilia. This is largely due to their greater activity associated with the relatively more efficient circulatory and respiratory organs. Warm and well-oxygenated blood at a more or less constant temperature circulates freely all over the body, endowing the limbs with considerable power of activity. A like activity either of brain or muscle is not to be expected in the Amphibia or the Reptilia. The skeleton of the mammal is designed with a view to *efficient* walking and running. Now *Diplodocus* being a reptile, we are not entitled to expect that its limbs should be arranged on the mammalian plan. Our study of its limb-bones confirms this anticipation. Its character, we hope, has been vindicated; it no longer can be said to have played a part for which it was not intended by nature.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. London, July 6, 1917.

Address to the Conference of Delegates. By John Hopkinson, F.L.S., F.G.S., F.Z.S., Assoc. Inst. C.E., President.

The Work and Aims of our Corresponding Societies.

It is nearly forty years since I suggested that the Delegates from provincial societies should hold a Conference at each meeting of the British Association, subsequently arranging for the first Conference to be held at Swansea in 1880. Although sanctioned by the Council of the Association it was not an official Conference, being the first of five managed and supported financially by the Delegates only. Having then been in the chair I accept with the greater satisfaction after so many years the honour conferred upon me to preside at the present Conference.

At the Conference held at Swansea in 1880 the following resolution was passed: "That this Conference recommends that at future meetings of the British Association the delegates from the various scientific societies should meet with the view of promoting the best interests of the Association and of the several societies represented." With this end in view it seems to me that Mr. Symons' address was particularly appropriate, for it is surely in the best interests of the Association as well as of its Corresponding Societies that concerted systematic work should be done.

The main object of our Societies is, or should be, to undertake local scientific investigation, and we are here assembled chiefly to discuss the best means of doing so and of obtaining the most valuable results. While all should work to the same end, that end, whatever it may be, can best be achieved by all working in the same manner, or at least on some definite plan, so that the results may be comparable.

It is not, however, to stimulate and direct scientific investigation only that this Conference should aim; there is also for it the wider field of influencing public opinion on the importance of far greater attention than at present being given to scientific education and to many problems concerned with the future welfare of our nation in which science may lend a fostering hand. There is no other country in the world which has nearly so many scientific societies as we have. There are on our list 120 Corresponding Societies (ninety Affiliated and thirty Associated) with an aggregate membership exceeding 46,000, subject to a slight reduction, as some of these societies are represented individually as well as by the Union to which they belong, and some have members who are also members of other societies on our list, but we may, I think, estimate the number of individual members represented as not less than 45,000, while Principal Griffiths, in his address at our Cambridge Conference, in 1904, estimated the total number of scientific societies in the kingdom as about 500 with a membership approaching 100,000. If we could all agree upon some beneficial project what an immense influence we might have! . . .

For Section C, Geology, much good work has been done by the Corresponding Societies, especially for the Committee on Geological Photographs, which was formed by the joint action of the Section and the Conference of Delegates at the Bath meeting in 1888. The photographs (a very large number) are deposited in the Geological Museum in Jermyn Street, where they may be seen; also numerous lantern slides which are lent for lectures. The Committee is still in existence and photographs are acceptable.

Other important geological subjects which have been brought before our Conference are earth-tremors, underground water, and coast-erosion, in the investigation of one or other of which all our Corresponding Societies may help.

The subjects embraced in Section D, Zoology, are by far the most attractive to members of our natural history societies, to whom we owe nearly all our knowledge of the distribution of animal life in the British Isles, far more perhaps of that of the Invertebrata than that of the Vertebrata, about which much was known in very early days. It should be the aim of all such societies to compile and publish lists of the animals inhabiting their areas, recording their localities, carefully noting their habitats, and studying their habits and life-histories. Increasing attention is being paid to our Invertebrate fauna, but there is still very much to be done, especially in the collection and study of the microscopic forms of life in our rivers, lakes, ponds, and ditches, on our stately trees and humble mosses, and even in our soils. Almost every tuft of moist moss teems with animal life which will well repay microscopic examination.

There is another aspect of the subject which has frequently been brought before us, that is the preservation of our native fauna. In endeavouring to prevent the destruction of rare animals or of those approaching extinction all may help. We cannot well make sure of the presence of a rare moth or butterfly without capturing it, but there is never need to take a large series, as is the practice of some entomologists. With birds and mammals it is different; they can mostly be identified by the practised naturalist without shooting them. There are birds, such as the rook and the wood-pigeon, which should be reduced in number, as they are so destructive to our field and garden crops, but such birds as hawks and owls, which are persecuted by gamekeepers, are our farmers' best friends, and their extermination ought not to be allowed. The same may be said of all insectivorous birds. Hawks may occasionally kill a partridge or even a pheasant, the beautiful kingfisher may take a few fish, but the food of the owls, with the exception of a few rare species such as the eagle owl and the snowy owl, consist almost entirely of small rodents.[1] With regard to the species which should be protected, the ornithologists in a natural history society can render County Councils valuable help. An order for the protection of certain birds was

[1] Taken out of a barn-owl's tree at Keswick in Norfolk in April, 1911, were 114 "pellets" containing the skulls of 19 very small rats, 126 long- and short-tailed field-mice, 69 shrews, and 3 small birds (perhaps greenfinches), but no game.

issued by the Hertfordshire County Council in 1895 on the representation of the Hertfordshire Natural History Society, the schedule being drawn up by ornithological members of the Society and accepted by the County Council. . . .

The subject of Museums comes, I think, most appropriately under this Section, for they are of very great educational value. One of the most important committees of the Association was that appointed in 1886, by the co-operation of Sections C and D and the Conference of Delegates, for the purpose of preparing a report on the provincial museums of the United Kingdom. The Committee was very expeditious, thanks to the energy of its Secretary, Mr. F. T. Mott, presenting in the following year a valuable report which appeared in the Report of the Association for 1887 (pp. 97–130) and a further report the next year (Report for 1888, pp. 124–32). In the first report there are tables (I) giving particulars of 211 provincial museums under headings extending across two pages, (II) an approximate estimate of the number of specimens contained in these museums, and (III) a list of collections of special interest indicating the museums in which they are preserved. A large portion of this report is occupied with "Discussion of Details" under thirty-six heads. The second report considers "the ideal to which provincial museums should endeavour to attain", and suggests "practical methods for approaching that ideal". It is not too much to say that these reports are invaluable, not only to those who have the management of museums, but also to all scientific workers who wish to know where, apart from our national museums, the materials for study in their own branch of science are to be found.

The Hertfordshire County Museum at St. Albans—the only one with which I am connected—was not then founded, but I may mention that it is visited largely by children from the Board Schools in the neighbourhood, who take an intelligent interest in the exhibits, quickly find out accessions, and collect and bring to the Curator objects they wish to know the names of, presenting to the Museum any worthy of acceptance. To young children there is one drawback in a museum, which has been felt at St. Albans: they wish to handle the specimens, rightly judging that by so doing they can learn more about them than by merely looking at them. Every museum should, if possible, have duplicates of the commoner objects, accurately named, to lend to schools. . . .

In walking over the Welsh hills I have repeatedly come across roots and stumps of trees in the peat-mosses which frequently cover them; they are evidences of former forests. The land is worthless except for the value of the peat, the removal of which would, for its valuable products, not only as a fuel, well repay the expense, and the ground would be rendered suitable for planting coniferous trees. It is true that most of our peat-covered mountain-land is above the elevation at which it is generally considered that trees will flourish (1,500 feet), but if they did so in the past there seems no reason why they should not do so in the future, for it is far more likely that our climate has become warmer since trees grew on that land than it is that it has become colder. We have also large areas of waste land at lower elevations, extensive slopes which are too steep for ordinary cultivation between, and on sheep-farms much very poor grazing-land which would be more profitably used in growing timber. As to the best trees to be planted at different elevations and on different soils, at least by private landowners, no doubt there are many botanists in our societies who could greatly help with their advice. In the last half-century we have doubled our imports of timber and now do not produce more than a tenth part of our requirements, although our climate is admirably suited to the production of nearly the whole.

We are far behind most European countries in the relative area of our timbered land. For instance, nearly half the area of Russia and of the Scandinavian countries is wooded, about 26 per cent of the area of Germany, about 17 per cent of that of France, and the same of Belgium, the most densely populated country in Europe until its devastation and depopulation by the Germans, but only about 4 per cent of the area of the United Kingdom, which will probably be reduced owing to the requirements of our war to not more than 2 or 3 per cent.

Next to fostering agriculture let it be your aim, individually as well as collectively in your capacity as members of societies working in harmonious co-operation, to promote to the best of your ability the re-afforestation of our country. By encouraging these two industries you will help to secure its future safety and prosperity.

II.—Report on the Tungsten Deposits of Essexvale, Umzingwane District.[1] By A. E. V. Zealley, A.R.C.S., Geologist to the Southern Rhodesia Geological Survey.

THERE seems to be general opinion that the tungsten deposits at Essexvale consist only of so-called alluvial or rubble wolframite, and that reefs have not been found. This is not true. Some reefs have long been known, and the excavation of the rubble has led to the uncovering of others, which, so far as can be judged without actual sampling and development, offer good prospects for mining. But hitherto there has been a strange reluctance to undertake mining operations on the reefs, whilst the work on the rubble has been largely desultory.

Position.—The known tungsten reefs lie within an east and west rectangular block of country of about 9½ square miles area lying immediately to the north of Essexvale Siding and mainly west of the railway. The reefs extend from the neighbourhood of "The Ranche" (2¾ miles north-west of the Siding) to the Native Church (1½ miles north-east of the Siding). Sixteen distinct reefs are known, eleven of which have had a little work done on them from time to time.

History.—The deposits were first prospected in 1906. In the ensuing two years a fair amount of ore was produced, but in 1909 the production ceased. A little interest was again taken in the deposits in 1912–13, but there was no production in 1914–15. At

[1] Reprinted from the *Bulawayo Chronicle* of May 18, 1917.

the end of that period a local syndicate extensively sampled some thousands of tons of rubble and made trial crushings. The grade was found to be just too low for profitable working by the methods then employed. During 1916, however, determined efforts have been made by other workers to test the rubble of two restricted areas.

Altogether about 85 tons of concentrate valued at £7,165 has been marketed. The returns for 1916 are $2\frac{1}{2}$ tons valued at £467. This was produced by one worker with a few natives in a five-foot rotary diamond washer, and by one man on another claim who hand-picked rubble and recovered 1,600 lb. of wolframite.

The prospecting done on a few reefs that have been opened has nowhere been for more than a few feet below the surface. This may be due chiefly to the fact that the deposit upon which serious prospecting work has been undertaken is from its nature the least likely to prove profitable.

Geology.—The known tungsten-bearing tract of country occupies the central portion of an irregularly oval mass of granite about 8 miles long and 5 miles across at the widest part. The long axis of the mass trends north-west to south-east. This granite body forms the floor of a wide depression which is traversed by two permanently flowing streams, one of which is known as Fern Spruit. The granite appears to pass beneath the surrounding rim of epidiorite and felsite hills. The soil is a pale-red sandy loam. There are very few exposures excepting in the streams and an occasional small but bold granite kopje. The granite almost wherever seen is coarse-textured and massive, that is, not schistose. It is a hornblende granite, and is thus different from the large granite masses of Rhodesia. Patches of epidiorite, probably inclusions of country rock, and dykes and other bodies of felsite are occasionally encountered, particularly near the eastern edge.

The Reefs.—The tungsten reefs consist of *greisen* composed chiefly of a soft greenish-yellow mica or of mica, fluorspar, topaz, and secondary felspar. This rock weathers soft and rusty brown. The greisen has arisen by the action of vapours on a porphyry or aplite (fine-textured white granite free from hornblende and mica). With the greisen of each reef is a variable amount of rather white glassy quartz forming strings or large lenses in the greisen, and evidently connected with the greisenization, that is, deposited at the same time and by the same agency as the mica, fluorspar, topaz, tourmaline, chlorite, wolframite, and scheelite of the greisen.

The constant presence of the quartz lenses as part of the greisen bodies is a great help in recognizing the presence of the greisen. Those parts of the greisen which contain little or no quartz very rarely crop out, and thus may easily escape discovery. No tungsten reefs have been found without the quartz, although it is quite conceivable that such exist.

The quartz strings expand into lenses exceeding 20 feet in width, and thus make low hillocks such as those at "The Ranche" homestead; again two-thirds of a mile to the south-east of this, and at the Native Church a mile and a half north-east of Essexvale Siding.

The reefs vary from 200 yards to about a mile long. The two most promising reefs exposed are respectively about a mile long and half a mile long so far as proved. These are the Rhoda reef in the north-eastern portion of Plot 27, and the reef running through the Lunar and Moon blocks near the common boundary of Plots 37 and 38.

With one exception the reefs examined strike east to west and dip north at angles varying between 30° and 55°. The reef on Plot 4 strikes north-west to south-east and dips north-east at 53°.

The width of the reefs is of course variable owing to the lenses of quartz. Apart from the quartz lenses, the width averages three feet, and is surprisingly constant.

In each instance the country is coarse massive hornblende granite without signs of shearing or faulting between the reef and the country. It appears, therefore, that the aplite was injected along master joint planes caused by the contraction of the granite on consolidating, and not in fissures caused by faulting. This may have an important bearing on the persistence of the greisen bodies below the surface. In a few instances the mica greisen has a slightly schistose appearance. In a few places greisenization of the country is suspected, but this is on a small scale only, and no tungsten ore has been discovered in it.

With the exception of the Union Jack reef in the north-west corner of Essexvale Reserve the aplite has been completely greisenized so far as can be judged by the small amount of reef exposed. At the Union Jack the intrusion exceeds six feet in width, but about a third of it consists of white aplite apparently ungreisenized.

Stockwork Deposit.—The block upon which most work has been done differs from the above blocks, which may be taken to be normal. The occurrence in question is situated on Tungsten Kopje, a prominent hill of massive hornblende granite with a low ridge extending about 300 yards to the east and a longer one to the west.

The fact that a large amount of float wolframite occurred immediately around the hill led to prospecting on the hill, with the result that a stockwork deposit was discovered extending along the eastern and western ridges and on the north flank of the hill.

Throughout the massive hornblende granite of this zone streaks and seams of aplite containing gashes of quartz are scattered rather sparsely and quite indiscriminately. These seams run in all directions and at all angles, many are nearly flat, but some are vertical; they make small saddles in several places, but pursue irregular courses, and expand and die out quite irregularly. They average a few inches wide and in no instance exceed a foot. None are traceable for more than a few yards. The greisen always carries streaks of quartz and occurs on one or both sides of the latter. The aplite varies in degree of greisenization. In some parts the greisen consists of sugary quartz and pyrite with very fine wolframite scattered through it but invisible to the naked eye. Such a rock weathers brown and strongly resembles sandstone. It is always present in the rotary concentrate. In other parts the greisen consists chiefly of a soft yellow mica.

At the south-west end of this deposit a body of greisen about 6 feet wide, striking north to south and dipping about 40° E., has been opened and afforded rich patches of wolframite.

Minerals of the Greisen.—The minerals detected in the greisens comprise quartz, soft yellow mica, felspar, dark-green chlorite in rosettes, black tourmaline, pyrite (altered to cubes of limonite at the surface), fluorspar (blue, mauve, green, white, and colourless), topaz (pale brown and colourless), galena (rather rarely), pyrrhotite, wolframite, and scheelite.

Small quantities of each of these occur in the quartz. Here and there a bunch or streak of any one of them, including the tungsten minerals, lies in the quartz. The distribution of the minerals in the quartz or in the altered aplite is in fact generally patchy, as is always the case in greisens. Coarse aggregates of any one mineral are occasionally noted; for example, single aggregates of very large wolframite crystals weighing 235 and 157 lb are said to have been found at the stockwork deposit, and similar groups of crystals have been obtained at the Lunar Block (the specimen in the Rhodesia Museum weighing 172 lb. came from here). Pieces of wolframite weighing up to 8 lb. are not uncommon, and groups of pale pinkish scheelite crystals measuring 3 or 4 inches are to be found. The two tungsten minerals are commonly intergrown; but in spite of this and of the fact that scheelite, containing as it frequently does several per cent more tungstic oxide than wolframite, may be worth several pounds sterling per ton more than the wolframite, it was found that the scheelite was neglected by the workers; in fact, considerable trouble was taken by them to separate it from the wolframite and reject it.

Scheelite is a mineral very easily recognized, and the natives engaged in panning the concentrate should be taught to know it. Although it is not unlike quartz so far as colour is concerned—being white, pinkish, or yellowish—its characteristic greasy lustre, softness (it is easily scratched by the knife or by quartz), and heaviness are properties which differentiate it sufficiently from any of the minerals with which it is associated. If boiled in dilute hydrochloric acid it becomes coated with bright yellow powder soluble in alkali.

Among the dark minerals got in the concentrate, magnetite may be recognized (and separated) by the magnet, and limonite by being in brown cubes. Coarse and moderately fine wolframite is easily distinguished from the other black minerals by its greater specific gravity and chocolate-brown streak; it breaks into flat slabby pieces with lamellar structure owing to the presence of a single perfect cleavage; the flat surfaces are bright and shiny (submetallic to resinous lustre), whilst the cross fractures are dull. Ilmenite, which is rather abundant in very fine round grains in the concentrate of the rubble, is difficult to distinguish from fine wolframite by simple tests, and this fact had led to the rejection of the finest concentrate.

Mineralization.—In addition to the minerals common to greisen, the presence both in the stockwork and in the veins, of galena, pyrite, pyrrhotite, and presumably gold, together with the large amount and constant presence of a kind of quartz which is indistinguishable from the ordinary vein quartz of gold deposits, suggests that the Essexvale tungsten deposits are not normal greisens, but to some degree assume the characters of the gold-quartz vein type of deposit. In fact, they appear to form a connecting link between the two types. This theory is borne out by the character of the mineralization of the country rock alongside the greisen streaks in the stockwork deposit. The rock is pyritized (pyrite and pyrrhotite), and the felspars altered to sericitic aggregates.

The Rubble.—The richer patches of rubble lie within 100 yards of the greisens on the steeper ground and within about 25 yards on the flat ground.

Tests of this rubble indicate that the yield of wolframite (the scheelite as noted above being rejected) varies from 2 to 8 lb. per ton. In this estimate the occasional lumps of coarse wolframite are not included, and fine wolframite and scheelite in lumps of rock and free are also not included, since they are rejected.

In the instance of the western end of the Lunar Block reef it was stated that early in 1916, 1,600 lb. of wolframite was picked up from the surface by hand without any appliances, without even a prospecting pan, notwithstanding that the ground had been broken, turned over, and picked on at least one previous occasion.

Where the rubble is being more thoroughly tested, the ground, made up of angular quartz fragments, brown-weathered greisen, and sandstone-like aplite in a matrix of red loam, is hand-jigged on rocking-screens, the coarse wolframite being hand-picked from the screens. The fines are concentrated in a 5 ft. rotary diamond washer, which recovers the tungsten minerals and even the fine heavy minerals. The concentrate is then panned by hand. The coarse wolframite (pieces over half an inch) are picked by hand and the fines re-panned. Any coarse wolframite with adhering quartz is pestled and panned. The coarse and medium concentrate so obtained is remarkably clean wolframite. The finest concentrate consists of wolframite and scheelite, with a certain amount of quartz, felspar, epidote, hornblende, mica, zircon, and tourmaline, together with a trace of gold, and a fairly large quantity of ilmenite, limonite cubes, and magnetite. The finest concentrate is rejected under existing circumstances, but on a larger scale of operations concentrating tables and magnetite separators may be expected to give profitable results.

REVIEWS.

I.—A Pocket Handbook of Minerals. By G. Montague Butler. Second Edition. pp. x + 311, with 89 figures in the text. New York, John Wiley & Sons; London, Chapman & Hall, Ltd. No date. Price 11*s.* 6*d.* net.

THIS handy little treatise by the Professor of Mineralogy and Petrology in the University of Arizona has met with such a large demand that a second edition has been called for. The original scope and plan proved so satisfactory that no change as regards them was made, and the only difference in this edition is that additions have been made here and there to the original text where experience has suggested the need, and, of course, all typographical errors that have come to light have been corrected.

The mineral species are arranged in the customary order, and are described concisely, but sufficiently fully for the purpose of discrimination. Happy use has been made of heavier type to emphasize the more important or prominent features. Under each we find particulars of the chemical composition, hardness, lustre, colour, streak, cleavage (if any), transparency or opacity, specific gravity, simple blowpipe reactions, and crystal form. We may throw out the suggestion that now that portable, trustworthy refractometers are available, it would be advantageous in a subsequent edition to include details of the refractive indices and of the double refraction where it is present. In the case of a transparent substance a measurement of the refractivity will often settle its identity beyond doubt. The blowpipe reactions are such as can easily be carried out with an ordinary portable outfit. To facilitate the determination of mineral specimens, the more obvious physical characters are tabulated at the end of the book on a series of folded leaves; by consulting this table the inquirer may reduce the number of species to which a particular specimen might belong to two or three, and a reference to the fuller descriptions in the text will lead to the proper identification.

As a help to the prospector Professor Butler in a series of appendices gives the retail prices of good to very fine cut stones, the value of metals and minerals, a glossary of the technical terms and expressions used in the description of minerals, a table of the elements with their symbols and atomic weights, Mohs's scale of hardness, and von Kobell's scale of fusibility. The information given in the first appendix on the charges made by lapidaries for cutting stones is not sufficiently explicit. In the case of "fancy" stones the cost of cutting is based on the weight of the finished stones, whereas for diamonds it is the weight of the rough material that determines the cost, and the charge for faceting a diamond works out at more than fifteen times what it would be for an ordinary stone of similar size when cut. Few lapidaries undertake both classes of work. The author seems to be unaware that the standard weight practically all over the world is the carat of one-fifth gram, and not as defined by him. He points out in a note to the second appendix that the quotations for metals and minerals are those prevailing before the War; inasmuch as the large increases now obtaining will probably in most instances end with it, he has refrained from giving them. The publishers are open to severe criticism for their omission to give any indication of the date of publication; it is only the fact that the author in this note speaks of the "European" war that any clue as to the date is afforded. The curious use of two very different kinds of paper militates against the appearance of the book.

II.—New Species of Fossil Beetles from Florissant, Colorado. By H. F. Wickham. Proc. United States National Museum, 1917, vol. lii, pp. 463–72, pls. xxxvii–ix.

SOME fifteen new species are described and figured under almost as many genera, *Brachyspathus* being new, while all are comprised in the following families: Carabidæ, Coccinellidæ, Buprestidæ, Sampyridæ, Malachiidæ, Ptinidæ, Spondylidæ, Cerambycidæ, Bruchidæ, Otiorhynchidæ, and Curculionidæ.

III.—The *Zoological Record*, vol. lii, for 1915, has recently appeared and contains as usual papers on fossil as well as recent zoology. The volume for 1916 is in hand, and may be expected this time next year. The book is thinner than usual owing to the dearth of work and the difficulty of obtaining that from enemy countries. It is on sale, in the special parts, at the Zoological Society of London.

IV.—William Smith: his Maps and Memoirs.

THE story of William Smith, "the Father of English Geology" as he was styled by Professor Sedgwick long ago, has been told by his nephew, the late Professor John Phillips, by H. Woodward, Professor J. W. Judd, Mr. Sheppard, and many others (see Geol. Mag., 1869, 1870, 1873, 1877, 1892, 1897, etc.). Mr. Sheppard has recently described his maps (see Proc. Geol. Soc. Lond. in Geol. Mag., July, 1917, pp. 330–1). Now some 200 pages and 17 plates are issued in the Proc. Geol. Soc. Yorkshire for March, 1917. In this elaborate and carefully prepared work, Mr. T. Sheppard presents, in a graphic manner, Smith's career, his special work in Yorkshire, the history of maps, personal memorials, "claims" now first made public, and several of his manuscript memoirs. Besides this the author discusses earlier work on mapping by Owen, Lister, Strachey, Woodward, Desmarest, Pache, Michel, Whitehurst, Smeaton, the Board of Agriculture, Jamieson, Parkinson, and all Smith's maps in detail, so a fairly comprehensive view of this subject is unfolded. The illustrations are admirably selected for their purpose, and the paper (published at 5*s.*) should be in the hands of every geologist.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

June 20, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Pre-Cambrian and Associated Rocks of the District of Mozambique." By Arthur Holmes, A.R.C.S., D.I.C., B.Sc., F.G.S.

Beyond the coastal and volcanic beds of Mozambique (described in a previous contribution—Abs. Proc. Geol. Soc. 1916, No. 994, p. 72) the country assumes the form of a gently undulating plateau, gradually rising towards the west and diversified by innumerable inselberg peaks and abruptly rising clusters of hills. The dominant rock throughout is a grey biotite-gneiss. Interfoliated with this are occasional lenticular masses of hornblende-gneiss and amphibolite, and within these smaller bands of crystalline limestone are sometimes preserved. In many places the gneisses become garnetiferous, while eclogites and basic granulites also occur. Schists—referable to arenaceous sediments—are found only near the coast, where they are interbanded with gneisses; and, as the latter are mainly of igneous origin, they are thought to be intrusive into, and therefore younger than, the schists. As a general rule, the foliation and the banding of the gneisses are well defined in parallel uncontorted planes, the strike being commonly along, or somewhat north of, a north-east to south-west direction. In certain inselberg peaks, the strike sweeps round the contours, while the foliation surfaces dip quaquaversally from the summit. Into the gneisses later granites, belonging to at least two different periods, have penetrated, riddling them with enormous numbers of small intrusions, lit-par-lit injections, tongues, and apophyses. Rocks of later age are rarely met with; but in a few places dykes of picrite and pyroxenite have been found cutting the youngest pegmatites.

The succession of rocks in eight of the better-known districts is described, and the following general classification is based on the details thus provided:—

Ultrabasic Dykes.	Pyroxenites. Picrite.	Age unknown.
	Intrusive Contact.	
Granites and Coarse Pegmatites.	Biotite-Granites. Graphic Granite and other Pegmatites. Quartz-Veins.	Pre-Cretaceous and Post-Middle Pre-Cambrian.
	Intrusive Contact.	
Granulitic Granites, Pegmatites, and Associated Rocks.	Biotite-Granites (including Porphyritic varieties). Pegmatites and Aplites. Pyroxene-Granite and Quartz. Pyroxene-Diorite Series. Pyroxene-Granulites ?	Middle Pre-Cambrian. $Pb/U = 0{\cdot}14 - 0{\cdot}17$.
	Intrusive Contact.	
Gneisses and Associated Rocks.	Biotite-Gneisses and Gneissose Granites. Hornblende Gneisses. Amphibolites. Garnetiferous Gneisses, Granulites, and Eclogites.	$Pb/U = 0{\cdot}21$. Lower Pre-Cambrian.
	Intrusive Contact.	
Crystalline Schists and Limestones.	Quartz-Mica-Schists. Quartz-Magnetite-Schists. Hornblende-Garnet-Schists. Hæmatite-Schists. Forsterite Marbles, and other Crystalline Limestones.	

The above correlations of certain groups of rocks with the Lower and Middle Pre-Cambrian of other regions are based on the determination of lead-uranium ratios of zircons derived from the gneisses and granulitic granites respectively, the zircons having been obtained by crushing and panning the rocks in the field. The gneisses give a ratio of 0·21, comparable with a ratio of 0·24 obtained for Canadian zircons of Laurentian age. The granulitic granites give ratios of 0·14 to 0·17, comparable to those of radio-active minerals of late Archæan, that is, late Middle Pre-Cambrian, age in Scandinavia (Moss 0·12 to 0·15, Arendal 0·16 to 0·18, and Ytterby 0·15 to 0·17), Canada (Villeneuve, Quebec, 0·17), and India (Singar 0·14).

The rocks are described in detail, with tables giving the quantitative mineral composition and the specific gravities and radium contents. Numerous examples of contact phenomena between crystalline limestones and various types of igneous rock are recorded: pyroxene, amphibole, sphene, and soda-lime felspar being the new minerals chiefly developed, between granite and limestone, with garnet and scapolite in special cases.

With reference to the origin of the crystalline limestones and gneisses the following conclusions are arrived at:—

(*a*) The crystalline schists and limestones are interpreted as arenaceous and calcareous facies of an ancient sedimentary series, their argillaceous complements being unrepresented unless they enter into the composition of the biotite-gneisses.

(*b*) The limestones have controlled the formation of hornblende-gneiss and amphibolite by their interaction with a granitic magma that elsewhere is represented by biotite-gneisses. The cores of the limestones have been enabled to resist further silicification by being thus enclosed within a blanket of rocks impoverished in silica.

(*c*) If the ancient sedimentary series included argillaceous formations, it is thought probable that the gneisses are composite rocks produced by the concordant injection of granitic magma into such formations. This view, although not proved, is supported by mineralogical and radio-active evidence, and by the fact that in certain inselberg peaks the banding of the gneisses gradually dies away as the slopes are ascended, the rocks passing into granulitic granite nearly free from biotite and showing few traces of foliation. These peaks are interpreted as the irruptive foci of granulitic magmas which fed the lateral intrusions represented by the surrounding gneisses.

It is shown that there are at least three types of inselberg peaks that owe their survival to peculiarities of structure and composition. The first type is that just mentioned, in which the foliation is less marked and the biotite content appreciably lower than in the surrounding gneisses. In the second, the peaks are mainly composed of granulitic granite (again poor in biotite compared with the gneisses), and in the third type the peaks are riddled with tongues and apophyses of pegmatite and aplite. In each case the greater resistance offered to denudation is related to the presence of less foliated and more felsic rocks than are found in the adjacent plains. There remains a fourth type—perhaps the most abundant—in which no differences have been recognized. Many of these seem to be isolated relics of gneissic escarpments; and it is suggested that desert erosion, involving the attack of slopes at their base by arid weathering, and the removal of disintegrated material by wind, is the most favourable condition for the development and maintenance of an inselberg landscape. Existing conditions of denudation are considered to be unfavourable to inselberg survival; for the peaks appear to be worn down by the removal of superficial layers by exfoliation more rapidly than the surface of the plateau is lowered.

2. "The Inferior Oolite and Contiguous Deposits of the Crewkerne District (Somerset)." By Linsdall Richardson, F.R.S.E., F.G.S.

In this communication a detailed description is given of the Inferior Oolite of the Crewkerne district.

Roughly speaking, the Upper Liassic Sands to the south-west of a line connecting South Petherton, Crewkerne, and South Perrott, are very similar to their equivalents in the Burton–Bradstock—Beaminster–Broadwindsor district. To the north-west of that line, however, limestones — largely made up of shell-débris—replace a considerable portion of the yellow sands of *moorei* hemera, "thickening" from about 18 feet at North Perrott ("Perrott Stone") to 78 feet at Ham Hill ("Riddings" and Ham Hill Building-Stone).

In the extreme south-western portion of this district, around say Drimpton, the *Aalensis* beds are also probably very similar to their equivalents in the Burton–Bradstock—Beaminster–Broadwindsor district, and at Furzy Knaps, near Seavington St. Mary (4 miles north-west of Crewkerne), what is seen of them is highly fossiliferous. East of Crewkerne, however, these beds "attenuate" and "die out" altogether between North Perrott and Yeovil Junction.

The *Opaliniforme* beds at Broadwindsor, Whaddon Hill, and Chideock Quarry Hill comprise, in descending order—

(*a*) Rusty Bed ;
(*b*) Very fossiliferous sandstone ; and
(*c*) Sands and sandburrs.

The equivalent of (*b*) is readily recognized at the Cathole Lane Section, Crewkerne, where it is very rich in ammonites. Above it are deposits which are with but little doubt equivalent to the Rusty Bed of more southern localities. East of Crewkerne, the *Opaliniforme* beds—like the *Aalensis* beds — "attenuate," the lower beds apparently disappearing first. They "die out" between East Chinnock and Yeovil Junction.

The *Scissum* beds are 6 ft. 2 in. thick at Broadwindsor, and very fossiliferous. They retain the characters exhibited at Broadwindsor in the area south of the L. & S.W. Railway; but at North Perrott, on the north, what appears to be the equivalent of their lowest portion is softer and thicker. The *Scissum* beds also fail between East Chinnock and the Junction.

The *Scissum* beds are succeeded by the *Ancolioceras* beds—at the Conegar Hill Section, Broadwindsor, two strata, each 1 foot thick. The *Ancolioceras* beds extend into the Crewkerne district: they are well exposed at the Misterton Lime-works and at other sections in the neighbourhood, and apparently were proved in the now filled-up quarry in Haselbury Plucknett village. Probably the *Ancolioceras* beds persist throughout the Crewkerne district.

The upper portion of the *Murchisonæ* beds is the main horizon for *Zeilleria anglica* (Oppel). In the neighbourhood of Beaminster specimens of this Brachiopod are very abundant. The true *Zeilleria anglica* beds are absent from the Conegar Hill Section, but occur at Drimpton, in the extreme south of the Crewkerne district, and apparently were met with at Haselbury Plucknett, east of Crewkerne.

Attached here and there to the top of the *Murchisonæ–Ancolioceras* beds is ironshot rock, doubtless of late *bradfordensis* date—the date of the *Rhynchonella ringens* beds of the Sherborne district. Thicker deposits may be present at Dinnington and Haselbury Plucknett. Deposits of *concavi*, *discitæ*, and, in places, of *blagdeni* hemeræ may also be present in the neighbourhood of Dinnington.

There is thus a great hiatus in the Inferior Oolite Series of the Crewkerne district, there being—except possibly in the neighbourhood of Dinnington—no rock present assignable to any hemera between those of *bradfordensis* and *garantianæ*—the latter the date of the wide-spreading Upper *Trigonia* Grit of the Cotteswolds.

The rock of *garantianæ* date varies considerably in lithic characters, thickness, and abundance of organic remains in the district.

It has not been possible to identify definitely the *Truellei* bed in the district. The main of the Top Limestones is of *schlœnbachi* date. The *Schlœnbachi* beds "attenuate" east of Crewkerne; but at Haselbury Mill Quarry, in what the author regards as their lower portion, is a very interesting Sponge Bed, similar in appearance to that exposed in the Peashill Quarry, Shipton Gorge (Dorset). This Sponge Bed is rich in microscopic organisms. The *Zigzag* bed (very similar in its equivalent in the Burton–Bradstock—Beaminster–Broadwindsor district) has been observed at North Perrott and Haselbury Mill Quarry.

The Scroff (*fuscæ* hemera) was apparently observed by J. F. Walker in a quarry near Misterton Church. Fullers' Earth Clay succeeds the Scroff.

II.—British Association for the Advancement of Science.

After consultation with members of H.M. Government and with the local authorities at Bournemouth the Annual Meeting of the British Association, which was to have been held at Bournemouth this year, has been cancelled; but the General Committee met in the Rooms of the Linnean Society, Burlington House, Piccadilly, London, on Friday, July 6, at 12 noon, and received the Report of the Council, and elected Officers of the Association and Members of the Council.

Meetings of the organizing committees of the various sections, the delegates of corresponding societies, the committee of recommendations, and the general committee have therefore been held. It has been decided to continue Sir Arthur Evans in the presidency for another year, while Sir C. A. Parsons, who would have presided over this year's meeting, will do so at the meeting which it is hoped will take place as arranged at Cardiff next year. The meeting this year would have been at Bournemouth, and that borough has repeated its invitation, which has been accepted, for 1919. Grants amounting to £286 were made in aid of such researches as were regarded as essential to carry on, having regard to present conditions. The new members of the Council of the Association are Dr. E. F. Armstrong, Mr. J. H. Jeans, Professor A. Keith, Professor W. H. Perkin, and Mr. W. Whitaker.—From the *English Mechanic*, July 20, 1917.

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ASSISTED BY

PROFESSOR J. W. GREGORY, D.Sc., F.R.S., F.G.S.
DR. GEORGE J. HINDE, F.R.S., F.G.S.
SIR THOMAS H. HOLLAND, K.C.I.E., A.R.C.S., D.Sc., F.R.S., VICE-PRES. G.S.
DR. JOHN EDWARD MARR, M.A., Sc.D. (CAMB.), F.R.S., F.G.S.
SIR JETHRO J. H. TEALL, M.A., Sc.D. (CAMB.), LL.D., F.R.S., F.G.S.
PROFESSOR W. W. WATTS, Sc.D. (CAMB.), M.Sc., F.R.S., F.G.S.
DR. ARTHUR SMITH WOODWARD, F.R.S., F.L.S., VICE-PRES. GEOL. SOC.

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ORIGINAL ARTICLES.

I.—Notes on the Pycnodont Fishes.

By Arthur Smith Woodward, LL.D., F.R.S.

(PLATE XXIV.)

THE Pycnodonts were the coral fishes of Mesozoic seas, with a deepened body, produced face, and a small mouth having grasping and grinding teeth, capable of obtaining their hard-shelled food from hollows and crannies. They are evidently not to be regarded as closely allied to any of the typical coral fishes of Tertiary and existing seas, which are spiny-finned teleosteans. They are merely *Lepidotus*-like and *Dapedius*-like forms with adaptations to a similar mode of life. The study of their skeleton is therefore of great interest.

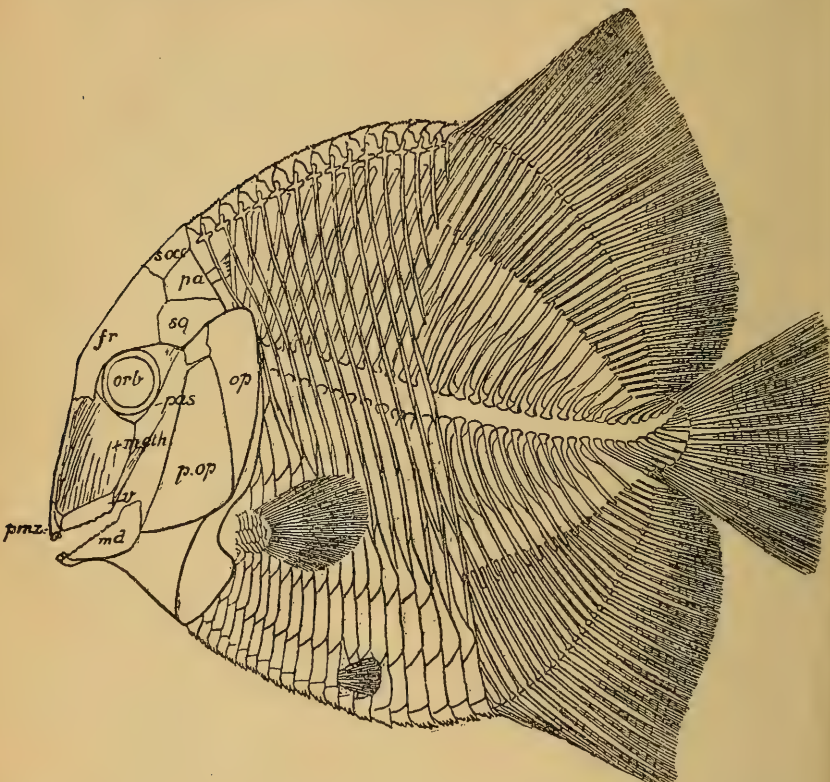
A complete summary of the osteology of the Pycnodonts, so far as known, was published in 1895–6 [1]; and, following the observations of other authors,[2] I have since had many opportunities of pursuing the subject further. A detailed study of *Microdon radiatus* in the forthcoming part of the Monograph of Wealden and Purbeck Fishes for the Palæontographical Society has especially led me to review the whole group of Pycnodonts, and I now venture to publish a few supplementary notes which these researches have suggested.

The normal arrangement of the roof-bones in a Pycnodont skull is shown in the accompanying restoration of *Mesodon* (p. 386). An elongated unpaired plate—the so-called supraoccipital (*s.occ.*)—forms the median ridge behind, and completely separates a pair of plates which are commonly identified as parietals (*pa.*). Each of the latter seems to represent a true parietal fused with a supratemporal; for in *Microdon radiatus*, at least, it is clearly traversed behind by two parallel transverse slime-canals. The bone also bears at the middle of its hinder border a smooth process with digitate end, which passes

[1] A. S. Woodward, *Catalogue of Fossil Fishes in the British Museum*, pt. iii (1895), pp. 190–8; also "On some Remains of the Pycnodont Fish, *Mesturus*, discovered by Alfred N. Leeds, Esq., in the Oxford Clay of Peterborough": Ann. Mag. Nat. Hist. [6], vol. xvii (1896), pp. 1–15, pls. i–iii.

[2] D. G. Kramberger, "De Piscibus Fossilibus Comeni, etc.": Djela Jugoslav. Akad., vol. xvi (1895), pp. 18–34, pls. v–vii, fig. 1. E. Hennig, "*Gyrodus* und die Organisation der Pyknodonten": Palæontographica, vol. liii (1906), pp. 137–208, pls. x–xiii; also "Ueber einige Pyknodonten vom Libanon": Centralbl. für Mineral., 1907, pp. 360–71.

beneath the antero-dorsal scales, and may perhaps be regarded as the post-temporal. It is, at any rate, noteworthy that in *Gyrodus*, where separate supratemporals and post-temporals appear to be recognizable,[1] the parietal is exceptional in lacking the small posterior process. The otic region is completely covered by a squamosal plate (*sq.*).



Mesodon macropterus (Agassiz); restoration, with cheek-plates removed, about two-thirds nat. size. Upper Jurassic (Lithographic Stone): Bavaria. *fr.* frontal; *m.eth.* mesethmoid; *md.* mandible, showing narrow dentary in front; *op.* operculum; *orb.* orbit; *p.op.* preoperculum; *pa.* parietal; *pas.* parasphenoid; *pmx.* premaxilla; *s.occ.* supraoccipital; *sq.* squamosal; *v.* vomer. Drawn by Miss Gertrude M. Woodward, chiefly from a specimen in the British Museum (No. P. 5546).

The frontals (*fr.*), which meet in a median suture, are the largest bones of the roof, sometimes ending abruptly just in advance of the orbit, sometimes tapering along the upper edge of the mesethmoid element of the snout.

[1] E. Hennig, Palæontographica, vol. liii (1906), p. 143, pls. x, xi.

In *Mesodon*, *Microdon*, *Stemmatodus*, *Gyrodus*, and *Mesturus*, the roof-bones form a continuous shield; but in *Cœlodus*, *Pycnodus*, and perhaps *Palæobalistum*, there is a small supratemporal vacuity on each side, bounded in front by the frontal, mesially and in part posteriorly by the "supraoccipital", laterally and in part posteriorly by the "parietal". In the British Museum this vacuity is well seen in specimens of a new species of *Cœlodus* from the Lithographic Stone of the Montsech, Lérida, Spain (Nos. P. 10999, 11000), in *Cœlodus costæ* from Castellamare, Italy (Nos. P. 1671, 1671*a*), in the so-called *Palæobalistum ponsorti* (which is probably a species of *Pycnodus*) from Mont Aimé, Marne, France (Nos. 28292, P. 1638), and in *Pycnodus platessus* (No. P. 1633) and *P. gibbosus* (No. P. 1634) from Monte Bolca, Italy. It evidently corresponds with the supratemporal vacuity in the existing teleosteans of the family Zeidæ,[1] and implies that in the Pycnodont genera just mentioned the lateral muscles of the trunk extended slightly forwards over the cranial roof. The "supraoccipital" is therefore probably the foremost dorsal ridge-scale enlarged and displaced forwards, while the part of the "parietal" bounding the vacuity behind is really a supratemporal.

The delicate and toothless pterygoid arcade, which was first seen in *Anomœodus* and *Mesturus*, has now been observed both in *Gyrodus* and *Cœlodus*; but the nature of the palatine bone remains uncertain. In the tritoral dentition there is still no satisfactory evidence of successional teeth. There are usually only two prehensile teeth in each premaxilla and dentary; but both in *Gyrodus* and in *Mesturus* there are three or four teeth in the premaxilla, four in the dentary.

Although the dentition is obviously adapted for crushing hard skeletons, it is curious that no example of a Pycnodont has hitherto been described showing the contents of the stomach. There appears to be only one such specimen in the British Museum—a small individual of *Pycnodus platessus*, shown of the natural size in Plate XXIV. Here the distended stomach is filled with the comminuted remains of bivalved shells, which are ornamented with radiating riblets, but are too imperfect for determination.

In this connection it is interesting to notice that some of the Pycnodonts agree with the existing *Balistes* in possessing clusters of small claw-shaped pharyngeal teeth. These teeth, found isolated, are known to palæontologists under the name of *Ancistrodus*.[2] In the British Museum I first observed them in their natural position in specimens of *Cœlodus* from the Montsech, Spain (No. P. 10996). They are seen in nearly all specimens of *Palæobalistum ponsorti* from Mont Aimé, France, and in *Pycnodus platessus* from Monte Bolca, Italy (Nos. 41083, P. 4386). They also occur in the type-specimen of *Xenopholis carinatus* and in a new specimen of the latter species (No. P. 10700). Similar teeth are seen in front of the mandible of a specimen of *Xenopholis* in the Court Museum, Vienna; and five

[1] E. C. Starks, "The Osteology and Relationships of the Family Zeidæ": Proc. U.S. Nat. Mus., vol. xxi (1898), p. 471, pl. xxxiii.

[2] W. Dames, "Ueber *Ancistrodon*": Zeitschr. deutsch. geol. Ges., 1883, pp. 655–70, pl. xix. See also figure by A. Gaudry, *Les Enchaînements du Monde Animal.—Fossiles Secondaires* (1890), p. 167, fig. 263.

of them, sufficiently large to have been the premaxillary and dentary teeth, have been found with a group of tritoral teeth of *Acrotemnus* in the Chalk of Belgium.[1] Larger and stouter examples of "*Ancistrodus*", therefore, are probably the prehensile teeth of Pycnodont jaws;[2] but the smaller examples, with translucent or transparent enamel, belong to the pharyngeal dentition.[3]

In *Cœlodus* the preoperculum is subdivided by an irregular transverse suture into two portions, the lower being the larger. The vertical slime-canal, which always traverses the preoperculum in Pycnodonts near its anterior border, passes directly into the upper portion, thus proving that it is not the operculum, as it has been named by Kramberger,[4] and also by Bassani and D'Erasmo.[5] The operculum in *Cœlodus* resembles that of other typical Pycnodonts, and the same bone in *Stemmatodus* is figured by Bassani and D'Erasmo[6] as a supraclavicle.

The ribs in Pycnodonts are comparatively short, extending not more than half-way to the ventral border. Each bears a paired laminar expansion tapering distally, as well seen in a specimen of *Gyrodus* in the British Museum (No. P. 1623*a*).

In the pectoral arch the supraclavicle has now been clearly observed in *Microdon radiatus* from the Purbeck Beds. Its exposed upper portion, crossed by the slime-canal, is triangular in shape, and its apex is situated at a short distance below the posterior process of the parietal bone.

In the typical *Mesodon* (Figure on p. 386), as in most Pycnodonts, the flank-scales are complete only in the lower part of the abdominal region, beginning with four or five in the transverse row immediately behind the pectoral arch and gradually diminishing to two or three in the last row just in front of the anal fin; the uppermost scale in each row tapering upwards to its riblet. In some of the earlier species commonly referred to *Mesodon*, however, such as *M. liassicus*, the scales are complete throughout nearly all the transverse rows; and I unfortunately made the mistake of representing this type of squamation in my first restoration of *M. macropterus*,[7] which is now corrected. In those genera in which the squamation is more or less nearly complete, either over the whole or the front half of the trunk, the scales are less deep and more numerous than in the genera in which the squamation is much reduced.

In nearly all Pycnodonts the ventral ridge-scales occur in uninterrupted series, and the small pelvic fin on each side is inserted

[1] M. Leriche, "Un Pycnodontoide aberrant du Sénonien du Hainaut": Bull. Soc. Belge Géol., vol. xxv (1911), Proc.-Verb., pp. 162–8, pl. A.

[2] e.g. specimen figured by A. S. Woodward, *Fossil Fishes of English Chalk* (Mon. Pal. Soc., 1909), pl. xxxv, fig. 8.

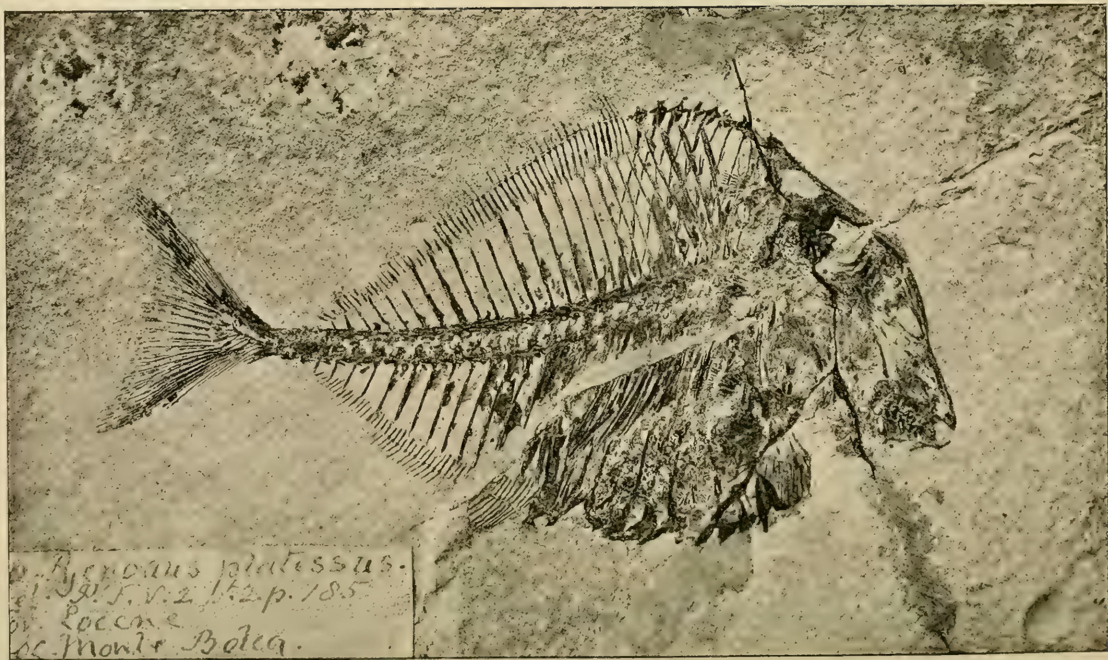
[3] e.g. specimen figured by A. S. Woodward, Proc. Geol. Assoc., vol. x (1888), pl. i, fig. 10.

[4] D. G. Kramberger, Djela Jugoslav. Akad., vol. xvi (1895), pp. 21, 31, pls. v, vi.

[5] F. Bassani & G. D'Erasmo, "La Ittiofauna del Calcare Cretacico di Capo d'Orlando presso Castellammare (Napoli)": Mem. Soc. Ital. Sci. [3], vol. xvii (1912), p. 227, fig. 12.

[6] Loc. cit., p. 221, fig. 9.

[7] A. S. Woodward, *Vertebrate Palæontology* (1898), p. 105, fig. 74.



PYCNODUS PLATESSUS, AGASSIZ. U. EOCENE, MONTE BOLCA, ITALY.

just above them. In most cases the two transverse rows of scales diverge at their lower end to admit the insertion of this fin and the intercalation of one scale behind it. One ventral ridge-scale at this point thus bears two facettes, one for its corresponding normal flank-scale, one for the intercalated scale. In *Pycnodus* and the so-called *Palæobalistum ponsorti*, one transverse row of scales seems to bifurcate at its lower end to accommodate the pelvic fin, and there is a gap in the ventral ridge-series immediately beneath it. The position of the anus is uncertain.

It is interesting to add that both in *Mesodon* and *Microdon* one or perhaps two small rhombic ganoid scales remain on the upper caudal lobe.

As to the systematic arrangement of the Pycnodonts, it is clear that the earliest species usually referred to *Mesodon* are the most primitive. I have placed them in a distinct genus in the forthcoming part of my *Monograph of Wealden and Purbeck Fishes*. *Gyrodus* and *Mesturus* are closely related to each other and diverge in several respects from other members of the group. The well-armoured Cretaceous forms, *Coccodus* and *Xenopholis*, are also peculiar. The general trend of specialization in the family seems to be as already stated in the British Museum Catalogue of Fossil Fishes.

EXPLANATION OF PLATE XXIV.

Pycnodus platessus, Agassiz; photograph of nearly complete fish in limestone, showing a mass of comminuted shells within the abdominal region. Nat. size. Upper Eocene: Monte Bolca, near Verona, Italy. British Museum, No. P. 1633.

II.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

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

V. The Perignathic Girdle of *Discoides cylindricus* (Lamarck).

(PLATE XXV.)

1. Introduction.

P. M. DUNCAN, to whose work we owe the standardization of our knowledge concerning the ambulacral structures of the Echinoidea, published in 1885 [1] a memoir "On the Perignathic Girdle of the Echinoidea", in which he definitely established the principles whereby this apparatus may be described and put to taxonomic use. The actual term "perignathic girdle", first introduced in that paper, was given with direct reference to the "perfect girdle around the jaws in *Discoidea*" (l.c., p. 207), although no detailed account of the peristomial structures of that genus was included. In the following year the same author, in collaboration with W. P. Sladen, gave a full description of the girdle of *Discoides*, in the light of the results reached in the previous work. The same two authors practically repeated their opinions on this topic in a later paper published in 1889.

[1] See list of literature at the end of this paper.

In 1884, in this Magazine, Duncan, to use his own words, "enlarged upon the nature of the peristomial structure of *Galerites albogalerus*" (*Conulus*), and proved, at least to his own satisfaction, that neither jaws, teeth, *nor perignathic girdle*, were developed in that species. To this opinion he and Sladen adhered in 1889.

During the same period Lovén had turned his attention to the perignathic structures of the Holectypoida, and published the results of his researches in 1888 in the course of his paper on the (probably misleading) discovery of *Pygastroides relictus.* In respect of the perignathic girdle of *Discoides*, Lovén's observations led him to conclusions as to its structure which were diametrically opposed to those of Duncan and Sladen in practically all features of importance. He also expressed the belief that both *Discoides* and *Conulus* were furnished with lanterns and teeth. To this Duncan and Sladen replied in 1889 by a regrettably dogmatic paper in which they repeated their previously expressed views, after the examination of a new series of specimens. Again they stated that the girdle of *Discoides* was composed wholly of interambulacral structures (ridges); that *Conulus* had no girdle at all, or at most a degenerate and functionless ridge; that it was extremely improbable that *Discoides* had any jaws; and, by inference, that it was practically certain that *Conulus* was totally devoid of a lantern. In 1892 Lovén published a fuller account of the girdles of the two genera, and, either in charity or sarcasm, referred to the work of the two British authors in a footnote only, without comment. He also had the intense satisfaction of being able to describe the pyramids of the lantern in *Discoides.*

Since the period of this somewhat strained, but eminently courteous, controversy, the present writer has published a more complete account of the lantern and teeth of *Discoides* (1909), and has recorded the discovery of indubitable teeth in *Conulus subrotundus* (1911). For the rest, the question of the characters of the perignathic girdle in the two genera remains practically in the unsatisfactory condition in which it was left.

The difference between the two interpretations of the girdle of *Discoides* can be best understood by a comparison of the figures given by the respective authors. If, following the advice of Duncan, we "very respectfully draw our . . . attention to [Lovén's drawing], fig. 2" (here partly reproduced in outline on Pl. XXV, Fig. 2), we find that each sector of the girdle is composed of four vertically elongated plates, the outer pair of which is united to the ambulacra by suture, while the inner pair articulates with three small polygonal plates on the interambulacral margin of the peristome. The outer pair consists of "processes" in Duncan's terminology, while the inner pair, with the three small plates, constitutes the "ridge". On comparing this drawing with Duncan & Sladen's very diagrammatic sketch (here copied in part, Pl. XXV, Fig. 1), the only discrepancies to be noticed are in the absence of the median interambulacral suture and of the small plates, and in the straightness of the sutures at the bases of the processes. (With the position of the ambulacral pores, another point of difference, we are not now concerned.) But the interpretation of their diagram given by the last-named authors affords a most striking contrast with that which must inevitably apply to Lovén's drawing. They maintained that the straight suture which comes at the adradial base of the projecting part of the girdle was the "interradio-ambulacral" (adradial) suture, and that the three large constituents of the girdle were all wholly interradial in position.

Two such opposite interpretations of a superficially straightforward structure demand reconciliation. The chief purpose of this paper is to show how this reconciliation can be effected. In the next paper of this series a new reading of the girdle of *Conulus* will be given (the denial of the presence of this structure is a lamentable and inexplicable lapse on the part of Duncan & Sladen), together with a general summary of the characters of the perignathic girdle in the Order. I hope to publish a comparison of the girdles of the Holectypoida and Clypeastroida at an early date, at the same time discussing the homologies of the peristomial structures of the Spatangoida.

2. The Perignathic Girdle of *Discoides cylindricus*.

(a) *Duncan & Sladen's Interpretation.* (Pl. XXV, Fig. 1.)

The outstanding characters of the perignathic girdle as represented by this diagram are: firstly, the presence of a low, thickened margin to the peristome in the ambulacral regions, perforated by three pore-pairs in each area; and secondly, the development of smooth, sloping ridges on the interambulacral margins, each composed of three flat plates, of which the central one is large and roughly rectangular in shape, while the outer (adradial) two are narrow adorally, expanding distally into prominent "ears". There is nothing inherently improbable in the ambulacral part of the girdle, for it would prove to be in a slightly modified Cidaroid stage of development. But the existence of three plates, representing three columns, in the interambulacra, would be a most extraordinary anomaly. It is true that in the somewhat obscure *Tiarechinus* and *Lysechinus* from the St. Cassian Beds of the Trias, the interambulacra are believed to show three columns (represented by one plate each) above the primordial, but to find such a feature in *Discoides*, especially when the rest of the interambulacra are built of the normal two columns, would be indeed marvellous. Even if the large central plate of the ridge be regarded as the primordial, and the two plates at the sides as the first two paired plates of the area, the figure becomes only less grotesque.

A comparison of the figure with a prepared specimen shows that the former is, as regards its drawing, a fair, though diagrammatic, representation of the appearance of the girdle. But the sutures near the ambulacral pores are not so straight as Duncan & Sladen make them, and the lateral "eared" plates of their ridge are certainly based upon the proximal ambulacral plates. There can be no possible doubt that their "interambulacro-radial" suture is really the basal suture of the process. The two "eared" lateral plates of the ridge are therefore certainly processes, as Lovén maintained. The true ridge, stripped of its radial marginals, would then be left as a flat, sloping plate of large size. This is certainly its general appearance in a specimen, but with careful lighting it may be found that the ridge plate is not flat but has a marked central concavity and several small irregularities on the exposed face. Its free (distal) margin is never, so far as I have determined, so straight as in the figure, and there is always a decided change in the direction of that margin when the processes are reached. But unless this large ridge represents simply the primordial interambulacral plate (which is almost inconceivable) it must necessarily be compound, and be crossed by sutures vertically or transversely or both. Duncan & Sladen expressed surprise at the apparent absence of sutures, but seem to have been satisfied that they were not present in the specimen from which their diagram was drawn. Their remarks (l.c., p. 237) imply that they were prepared to believe that sutures might exist in the ridge in some specimens and not in others. Such variability would be contrary to all experience in Echinoid structure, and one can only believe that their specimen was unsuitably preserved or cleaned for the display of the sutures.

To sum up: the lateral lappets of the ridge in Duncan & Sladen's diagram are in reality processes, and there is every reason to believe that the lack of sutures in the broad median plate is due to incomplete observation.

(b) *Lovén's Interpretation.* (Pl. XXV, Fig. 2.)

The beautiful figure published by Lovén in 1888 was copied by him in 1892, with the addition of another in which no sutures were shown. The twice published figure (here copied) was taken from the girdle of a depressed form of *D. cylindricus,* while the other represented a modification of the processes which Lovén thought to be restricted to the elevated, cylindrical form. Lovén suggested that the striking diversities between the superficial aspects of the two girdles might imply a specific difference between the two forms. In 1909 I showed that the "*forma elatior*" type of girdle could be found in specimens of the "*forma vulgaris*" (or "*depressa*"), and subsequent observations have confirmed this. The difference between the two types consists in the greater prominence of the processes in the "*forma elatior*" and in their inappreciable elevation beyond the apex of the ridge in the depressed form. This would appear to be a modification due solely to the size (i.e. age) of the specimen. The occurrence of the two kinds of girdle in the same form in no way vitiates the possibility of there being two distinct varieties of the species; on the contrary, it makes it the more probable that the two forms are definitely distinct. While the largest specimens of *D. cylindricus* that I have seen are all of the "*forma elatior*", I have examined numerous specimens of the "*forma vulgaris*" which were much larger than many decidedly cylindrical examples.

To turn to an analysis of the figure here copied: The outline of the girdle is for all practical purposes similar to that shown in Duncan & Sladen's figure. But the sutures at the bases of the processes are represented as curved, somewhat irregular lines, while the "lappets" of the processes, and indeed the whole ossicles, are shown to overlap the poriferous zones of the ambulacra. The central portion, or true ridge, of each section of the girdle is divided into two main sections by a more or less median suture, and at the margin of the peristome there are three small, unequal and irregularly shaped plates. In two of the areas, Nos. 4 and 5, Lovén, with his customary faithfulness to observation, has indicated some of the sutures in the ridges by broken lines, thus proving that in the other areas he could clearly distinguish the outlines of the plates. (No sutures whatever, either in the girdle or on the adoral surface of the test, are drawn in his figure of the "*forma elatior*", which was evidently a fully grown specimen in which secondary thickening had covered the original surfaces of the plates.) In one of the many preparations of the girdle of *Discoides* that I have made, there is a distinct median suture in some of the ridges, and fairly convincing evidence of the existence of a small triangular plate in the middle line at the peristomial border. By means of thin sections examined under crossed nicols, I have been able to confirm the presence of this small plate. I have not succeeded in tracing the two small plates which Lovén figures on each side of the median one; but the fidelity of his observations is so uniform that there can be no reasonable doubt of their occurrence, in some examples, at least. Lovén's drawing differs from that of Duncan & Sladen in these two fundamental points only: it is a faithful copy, not a diagram, and it contains a record of more complete observation. In its essential features I can confirm its accuracy from original observation. It is perhaps worth remarking that I made sketches which agree with Lovén's figure (with the exception noted above) before I had adequately studied his drawing. In the detection of sutures, particularly where they are faint and of unusual distribution, it is distressingly easy to be influenced by preconceived ideas. On re-examining my specimens after becoming familiar with Lovén's rendering, not only do the sutures previously detected seem far more obvious than before, but it is quite possible to imagine the presence of the two small plates on either side of the median one at the peristomial margin. However, experience has made me so wary in these matters that I have failed to convince myself of the certain occurrence of the sutures which would be the boundaries of such plates. That they were patent in Lovén's specimen I fully believe.

(c) *A suggested new interpretation.* (Pl. XXV, Figs. 3 and 6.)

In spite of the doubts entertained by Duncan & Sladen, there is no difficulty in recognizing the processes in the girdle of *Discoides*. Separated from the ridges, they present a marked similarity to those of *Plesiechinus* (see part iv of this series). It is in the ridges, which were hardly developed in the Jurassic Holectypoida, that the peculiarity occurs. The primordial interambulacral plate is generously represented at the peristomial margin in all five areas in *Discoides* (see Lovén, 1872, pl. xiv, fig. 125). In the majority of those Diademoida which have a strongly developed ridge, this structure is composed of a varying number of paired interambulacrals at its base, and has an apparently undivided plate along its free margin (see Duncan, 1885). It is possible that this unpaired plate may represent the primordial interambulacral (which is absent from the peristomial margin in these forms); or perhaps an outgrowth from it prior to its resorption. But in *Discoïdes*, where the primordial plate is situated on the peristomial margin, the distal part of the ridge is definitely composed of paired plates.

In *Plesiechinus* the only representative of the ridge is found as a semilunar inward prominence of the primordial interambulacral. It is, as far as my observations indicate, and as would be expected from its position, absolutely undivided by sutures of any kind. In *Discoïdes* the small median peristomial plate of the ridge is slightly, but definitely, more prominent than the rest of the structure. It is, almost certainly, the inner surface of the primordial plate. This small portion of the ridge must therefore be the homologue of the "ridge" of *Plesiechinus*.

In the Cidaroida and Diademoida the ridge is only connected to the normal coronal plates at its base, projecting almost vertically from their horizontal inner surfaces. In *Discoïdes*, on the contrary, the whole ridge, with the exception of an almost negligible rim at its distal extremity, is recumbent upon the interambulacrum, which is thickened so as to project in some cases (in internal aspect) to a greater height than the ridge itself attains. (See Pl. XXV, Fig. 3.) The degree to which the ridge extends above its supporting plates varies considerably, apparently with age. In some forms, where the radiating buttresses are low and feeble, the projection of the ridge may amount to nearly half its total height. It will be noticed in Lovén's figure (my Pl. XXV, Fig. 2) that the median suture of the ridge is directly continuous with that of the normal part of the interambulacrum. These distal plates of the ridge of *Discoïdes*, which constitute the greater part of the ridge, surely represent the inner surfaces of the paired interambulacrals next to the primordial, modified as supports, perhaps as actual "slides", for the inclined lantern. The projecting rim of the "ridge" need cause no surprise when the extraordinary pillar-like and carinate internal developments of the inner surface of the Clypeastroida, and indeed of *Discoïdes* itself, are taken into account.

If this interpretation of the girdle is correct, it follows that the girdle proper consists of the paired processes and small triangular peristomial plate of the interambulacrum; and that the bulk of the ridge is merely a specialized portion of the thickened paired plates. There is then no difficulty in considering the two small lateral plates of Lovén's figure, which form the interradial sides of the branchial incisions, as the first paired columnals; while the two large upper plates represent the somewhat expanded and modified inner surfaces of the second pair. All of the "ridge" except that part built of the small proximal median plate, is then not homologous with the ridge of a Diademoid. I would call it a "*false ridge*". It serves, like the buttresses recently described in *Plesiechinus*, as a mechanical support for the processes; and has the additional function of providing a smooth, slippery surface on which the splayed pyramids of the lantern could recline.

(d) *The position of the jaw-muscles.* (Pl. XXV, Fig. 6.)

There is a clearly defined articular facet on the upper part of each process which undoubtedly served for the attachment of the retractor muscles. I have failed to find any other indications of muscle-attachments upon the processes; and, to judge from the known characters of the pyramids, it seems improbable that a second pair of retractors was present.

The position of attachment of the protractor muscles is less clear. In those Clypeastroida which have paired processes, the protractors arise from the interradial sides of the processes, usually at or near their bases. Such a position for the protractors is quite impossible in *Discoides*, since there are no "interradiad faces" to the processes owing to the great height of the "false ridges". Hence the protractors must have been attached to some part of the ridge or "false ridge"; that is, in the Diademoid manner. I have not been able to recognize any muscle-impressions on the interradial parts of the girdle. Clearly the broad, shallow, elliptical depression which occupies most of the surface of the false ridge is not a muscle-scar. In some specimens there are very small and inconspicuous knobs on the false ridge at the upper corners of this central depression. They do not, however, suggest muscle-attachments, since these are normally roughened and depressed in Echinoid girdles. There remains the somewhat prominent "true ridge", on the actual margin of the peristome. If the interpretation of the girdle given above is correct, this is the proper situation for protractor attachments, by analogy with the Diademoida. It will be seen that in Pl. XXV, Fig. 6, I have based these muscles upon this median thickened plate. A further reason for this reconstruction—one that seems to me to be very cogent—is the normal direction of the protractor muscles. These, in the Diademoida, pass almost vertically from the low ridges to the tops of the hemi-pyramids. Owing to the prominence of the true ridge in *Discoides*, such a muscle arising from it would have free play for a considerable distance in all directions (see Pl. XXV, Fig. 6). Owing to the concave curvature of the rest of the "ridge", the only other position from which similar freedom could be attained would be the actual crest—a most unlikely place for the attachment of a strong muscle.

There is no evidence for the existence of radial compass muscles, nor of compasses in the lantern. Although negative evidence, when concerned with structures of such delicacy, is utterly unreliable, I have omitted them from the restored figure in view of their proved absence in the Clypeastroida. If it should be shown that *Discoides* had compasses, I should incline to find the attachment of their muscles on the true ridges between the pairs of protractors.

(e) *The nature of the "false ridges".*

If the foregoing argument respecting the position of the muscle-attachments of the perignathic girdle of *Discoides* is accepted, the interradial portion that I have called the false ridge is seen to be divorced from the true girdle as regards function. That it serves as a useful support for the very slender processes is obvious; and that it consists of the bevelled and otherwise modified edges of the very thick proximal coronal plates seems equally clear. In the previous article in this series (Geol. Mag., August, 1917), I showed that the processes of *Plesiechinus* are supported by thick buttresses which are built almost wholly of thickened interambulacral plates. The buttresses of the Jurassic genus are so similar in character, though far different in extent, to the carinate thickenings of the adoral surface of *Discoides*, that it is practically certain that the latter structures represent a phylogenetically later stage of the former. The buttresses of *Plesiechinus* pass towards the median interradial lines after leaving the processes, and subsequently return to the neighbourhood of the adradial sutures. In *Discoides* (see Pl. XXV, Fig. 3) they may be said to have a similar course, but each pair converges interradially to such a degree that fusion results. Thus the whole proximal part of each interambulacrum becomes much thickened, although elsewhere on the adoral surface the test is extremely thin. The false ridge therefore represents the bevelled edge of the fused buttresses.

Nevertheless, the false ridge is a more specialized structure than the preceding conclusion would demand. It is of closer texture than the ordinary parts of the buttresses, projects to a varying distance above them, and is hollowed in the centre. Clearly it must have served some special function, for which these characters are adaptations.

The strongly inclined (almost horizontal) pyramids of the lantern of *Clypeaster* actually articulate with the processes. There are no buttresses or analogous supports in the immediate vicinity of the peristome in this type. The lantern of *Discoides*, as Lovén and I have described it, was evidently "flaring" in character, though far more nearly vertical than is the case in *Clypeaster*. Since pyramids are interradial in position, it follows that they would lean over the proximal interradial plates, if splayed outwards. In *Discoides* these plates are much thickened; hence they must be bevelled off so as to afford play for the pyramids. It is at least likely, by comparison with the closely related Clypeastroida, that the pyramids may have actually leaned against the bevelled edges (false ridges) when the jaws were closed. This would be a preliminary to the actual articulation found in the last-named group. It may therefore be suggested that the smooth, concave surfaces of the false ridges served as "slides" for the pyramids, allowing them to be drawn up or down according as the teeth were withdrawn or extruded; and preventing the strain which would inevitably fall upon the muscles holding an inclined lantern together. The hollowing of the adoral faces of the false ridges would, as shown above, allow freedom of action for the protractor muscles.

3. Summary.

The conclusions of Lovén as to the composition of the perignathic girdle of *D. cylindricus* are confirmed in essential particulars, while

FIG. 1.

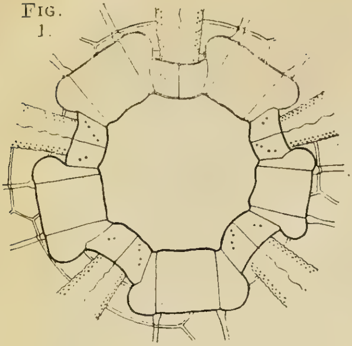


FIG. 2.

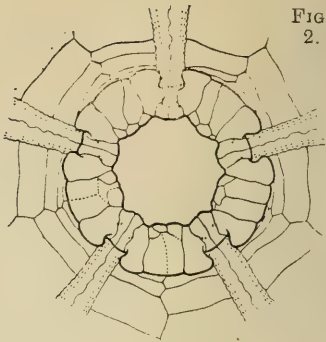


FIG. 3.

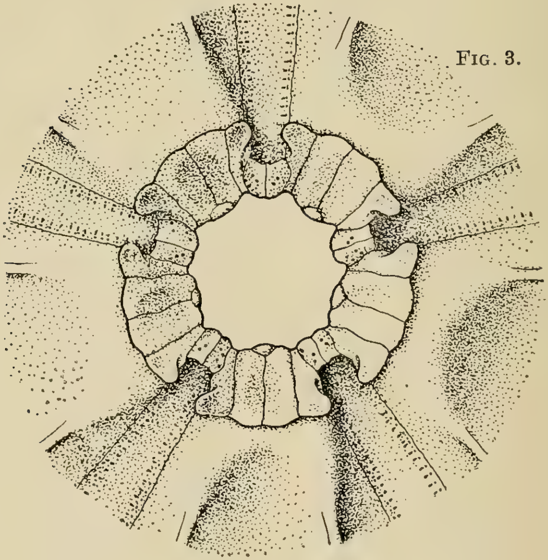


FIG. 4.

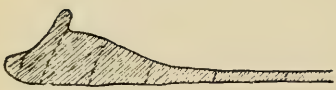
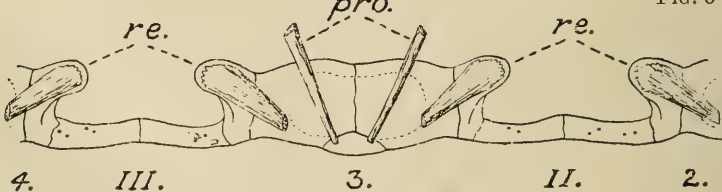


FIG. 5.

FIG. 6



H. L. H., del. Bale & Sons, imp.

PERIGNATHIC GIRDLE OF *DISCOIDES CYLINDRICUS* (Lam.).

those of Duncan & Sladen are shown to be based upon imperfectly preserved material. The processes, which may project freely for a varying distance above the rest of the girdle, are slender. The actual ridges are represented, as in *Plesiechinus*, by the slightly thickened and projecting inner surfaces of the unpaired primordial interambulacral plates. The rest of the interradial portion of the girdle is interpreted as being made of the bevelled edges of the buttresses which radiate over the interambulacra of the adoral surface. These sloping surfaces, here called "false ridges", are believed to be specialized and somewhat extended as "rests" or "slides" for the inclined pyramids; thus forecasting the articulation between lantern and girdle found in the Clypeastroida. The retractor muscles were attached to the upper parts of the processes, and it is argued that the protractors must have sprung from the small true ridges, the false ridges having no function as muscle supports. In the absence of positive evidence, radial compass muscles are presumed to have been absent.

4. List of Papers consulted.

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—— & Sladen (W. P.). 1886. "On the Anatomy of the Perignathic Girdle of *Discoidea cylindrica*": Journ. Linn. Soc. Zool., vol. xx, pp. 48–61.

—— —— 1889. "A note upon the Anatomy of the Perignathic Girdle of *Discoidea cylindrica*, Lamk., sp., and of a species of *Echinoconus*": Ann. Mag. Nat. Hist., ser. vi, vol. iv, pp. 234–9.

Hawkins (H. L.). 1909. "On the Jaw-apparatus of *Discoidea cylindrica* (Lamarck)": Geol. Mag., Dec. V, Vol. VI, pp. 148–52, Pl. VI.

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—— 1888. "On a Recent Form of the Echinoconidæ": Bih. K. Svensk. Vet.-Akad. Handl., Bd. xiii, Afd. iv, No. 10.

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EXPLANATION OF PLATE XXV.

Fig.

1. Copy of the figure of the perignathic girdle of *D. cylindricus* given by Duncan & Sladen (1889). The inner part of the figure, slightly reduced.
2. Copy of the figure of the perignathic girdle of *D. cylindricus* given by Lovén (1892). The inner part of the figure, slightly reduced; outline only.
3. The perignathic girdle of *D. cylindricus* (original). The figure is diagrammatic in that the sutures in the ridges were only seen in three of the areas, and the sutures of the coronal plates are omitted. The ridges project very little above the fused buttresses. The processes are intermediate in character between those of the "*forma vulgaris*" and "*forma elatior*" of Lovén. The specimen is depressed hemispherical in shape. The small true ridge is not quite so prominent as represented.
4. Section through the interradial line of the girdle of a specimen in which the ridge is unusually prominent, owing to the feeble development of the buttresses.

FIG.
5. Corresponding section of a specimen like that shown in Fig. 3; the ridge hardly projecting above the buttresses.
6. Diagram of the probable disposition of the jaw-muscles: *re.* retractors, *pro.* protractors. The radial compass muscles are omitted, being probably absent. The concavity of the false ridge is indicated by a dotted line. The girdle is shown from the oral view, so that the height of the processes and ridges is made to seem less than the actual by perspective due to their inclined character.

III.—EVIDENCE SUGGESTIVE OF CHARNIAN MOVEMENT IN EAST KENT.

By HERBERT ARTHUR BAKER, B.Sc., F.G.S.

(WITH TWO MAPS: PLATES XXVI AND XXVII.)

A COMPARATIVE study of the whole of the evidence concerning the Palæozoic floor beneath the South-East of England and the manner in which the various members of the Mesozoics are disposed upon it has led the present writer to conclude that the area, originally defined by Professor P. F. Kendall,[1] over which the effects of the operation of a "posthumous" Charnian axis may be discerned, can be greatly extended, more particularly to the eastward. The evidence, indeed, strongly suggests the presence of a second Charnian axis beneath Suffolk, proceeding thence south-eastward to North France.

East Kent lies on the western flank of this alleged Charnian ridge, and in view of the greater abundance of deep borings there, furnishes the best area in which to study its influence upon both the Palæozoic and Mesozoic rocks. With regard to the former, all the steadily accumulating information concerning the structure of the South-Eastern coalfield points to the presence, eastward of Kent, of a ridge or barrier of a Charnoid or Malvernoid trend, which appears to have been a potent factor during the deposition of the Kentish Carboniferous, and which probably now separates the coalfield from that of the Pas-de-Calais. In Kent the Lower Coal-measures, in the strict sense, are absent, and have apparently never been deposited, and there is no sign of Millstone Grit. The Middle Coal-measures lie unconformably upon the Carboniferous Limestone. The latter has been reached in several borings, particularly in North Kent, since the general dip of the Carboniferous in Kent is to the south-west. There is an area, a little to the north of Ebbsfleet, where, beneath the "blanket" of Mesozoic strata, the Carboniferous Limestone emerges from beneath the Coal-measures. For some five or six miles to the south-west of this zone of Carboniferous Limestone, the surface of the Palæozoic floor in East Kent is occupied by a succeeding "outcrop" of Middle Coal-measures, and these in their turn are succeeded by the Transition Coal-measures which cover the remainder of the surface of the known coal-basin to the south and west, to and beyond Dover. The general strike of the strata in the field is about 30° S. of E. and N. of W. A tendency of both Middle

[1] Kendall, "Sub-Report on the Concealed Portion of the Coalfield of Yorkshire, Derbyshire, and Nottinghamshire": Final Report Royal Comm. Coal Supp., pt. ix, 1905.


MAP 1
RAMSGATE
Ebbsfleet -51
Stodmarsh -48
Walmestone -23
XCANTERBURY
Trapham -224
Woodnesboro' -104
Mattrice Hill -55
Goodnestone -227
Chilham -478
DEAL
Fredville -420
Tilmanstone -232
Barfreston -336
Ripple -92
Ropersole -621
Waldershare -418
Maydensole ?
Oxney -163
English Miles
Brabourne -1855
Ellinge -938
DOVER
Dover -916
FOLKESTONE
Contours of the Palæozoic Floor in East Kent when the base of the Gault is considered as a datum - plane
By H. A BAKER, B Sc., F G S
Numbers signify depths in feet below base of Gault

and Transition Measures (but particularly the latter) to thin in an easterly direction has been observed.[1]

The present contours of the Palæozoic floor in East Kent must differ considerably from those presented by it during the time of the encroachment upon it of the Lias and Oolites. This is in consequence of the severe post-Jurassic earth-movements which have affected the South-East of England. The most important of these movements occurred in post-Cretaceous times, and that which had the greatest effect upon the Palæozoic floor was the one which resulted in the uplift of the Weald. Its chief effect upon the old floor in East Kent was to decrease very considerably the south-westerly slope. Considering, for example, the average downward slope of the Palæozoic floor from Ripple to Ellinge, it is now seen to be about 51½ feet to the mile, whereas in pre-Cretaceous times it must have been more than 110 feet to the mile. Consequently, in considering the disposition and variation in thickness of the members of the Mesozoic cover in relation to the old floor upon which they successively encroached, it is necessary to have some idea of the form of the latter as it was during the time of the deposition of these Mesozoics. Map 1 (Plate XXVI) is inserted here in which an attempt is made to eliminate the effects of post-Lower Cretaceous movements from the Palæozoic floor by considering the base of the Gault as a datum-plane and drawing a system of lines through points on the floor at equal depths below it.[2] This method naturally suffers from the imperfections of artificiality, and, of course, gives only an approximation to the true pre-Upper Cretaceous contours of the floor, since no allowance has been made (nor, in the circumstances, can be made) for the variation in depth of the Gault sea; but, speaking generally, the chief error involved is that the south-westerly slope of the floor appears somewhat less than it must actually have been. The point, however, is one of no importance for our present purpose.

The map shows very clearly indeed that in pre-Cretaceous times the Palæozoic floor of East Kent was part of the western flank of an elevated ridge lying to the north-east of the Ebbsfleet–Deal area, and possessing a distinctly N.W.–S.E. trend. Westward, however, the influence of the ridge is seen to die out. The contours present one or two features of special interest. The lines do not everywhere accord with those of a peneplain, but suggest, rather, immature denudation, or, at any rate, interruption and readjustment of the conditions under which denudation was progressing, by a movement of uplift in the north, probably accompanied by faulting, along a new and discordant line, viz. roughly east and west. An interesting subsidiary ridge or spur (or disturbance) crossed the area, entering Kent in the neighbourhood of Deal and dying out near Ropersole.

Turning now to the consideration of the features presented by the Jurassic strata in proximity with this N.W.–S.E. ridge, we find abundant evidence not only of the existence of the ridge in Jurassic

[1] Newell Arber, Trans. Inst. Min. Eng., vol. xlvii, pt. v, pp. 677–724, 1914.

[2] See Table I, p. 402, at end of paper.

times but also of the occurrence along it of repeated movements of uplift, in fact "posthumous" movements. It is significant, too, that the series of disturbances which can be traced is in remarkable agreement with the movements cited by Professor P. F. Kendall[1] as having occurred along the line of his celebrated Charnian axis. In the East Kent Jurassics illustrations may be noted of practically every kind of evidence that superincumbent strata can yield concerning the proximity of an axis of instability. The detailed account of the Jurassic succession in the deep borings at Brabourne and Dover, given in a Survey memoir,[2] is most interesting from this point of view. At Brabourne, although Lower, Middle, and Upper Lias are represented, the total thickness is but 140 feet, and at Dover, although all three divisions apparently still occur, the total thickness of the formation has dwindled to less than 40 feet. At several horizons planes of erosion occur, and rolled fragments, nodules, and broken fossils are abundant.

It is to be regretted that similar detailed accounts of the Lias proved in some five or six other deep borings in East Kent are not as yet available. At present we have little more than the recorded thicknesses to work upon (and even these sometimes differ where more than one record exists), and so many different circumstances combine in affecting the thickness of a deposit that, in general, it would be scarcely safe to base any definite conclusions on it alone. Nevertheless, in the present case, the tracing of isopachyte systems in the Jurassic strata of East Kent (Map 2, Plate XXVII) results in a series of lines revealing the closest sympathy with the pre-Upper Cretaceous contours of the Palæozoic floor and bringing out clearly the north-easterly encroachment of the Mesozoics upon the subsiding ridge.

In the case of the Lias the evidence[3] is sufficient for the insertion of three isopachytes, viz. 0 (feather-edge of formation), 50 feet, and 100 feet. We see that with proximity to the easterly ridge the isopachytes reveal a marked tendency to take on a N.W.–S.E. trend. The influence of the Deal–Ropersole elevation upon the 0 isopachyte of the Lias is interesting.

Passing to the Oolites we have more data to work upon and the results are still more interesting. What detailed information we possess concerning the Oolite succession in the borings, adds to the evidence in favour of posthumous movement along the easterly ridge. At Dover, as in Kendall's area, there is a marked non-sequence between the Oolites and the Lias. The Inferior Oolite, which undergoes a remarkable attenuation in Northamptonshire, and becomes more and more sandy as the Charnian axis is approached, is doubtfully represented at Dover by less than 30 feet of calcareous sandy grit and clay, and at Brabourne by about 40 feet of muddy,

[1] Kendall, loc. cit.

[2] Lamplugh & Kitchin, *On the Mesozoic Rocks in some of the Coal Explorations in Kent* (Mem. Geol. Surv.), 1911. N.B.—It is not proposed to deal fully with this evidence here. The reader is referred to the memoir quoted, pp. 5–56, for abundant details, and to p. 94 for the significant conclusions arrived at by the authors.

[3] See Table of Thicknesses (Table II), p. 403, at end of paper.


MAP 2
0 1 2 English 4 Miles 6 8
RAMSGATE
Eobsfleet
Stodmarsh
Walmestone
WEALDEN OVERLAP
CANTERBURY
Trapham
Woodnesboro
Murrice Hill
?
LOWER GREENSAND OVERLAP
Chilham
Goodnestone
BATHONIAN
DEAL
LIAS OVERLAP
Fredville
Tilmanstone
Barfreston
Ripple
Ropersole
Waldershare
Maydensole
Oxney
Guilford
OVERLAP
LIAS OVERLAP
Brabourne
Ellinge
DOVER
Dover
FOLKESTONE
0
50
100
150
200
250
300
400
500
600
700
1000
Isopachyte – Systems of the Jurassic in East Kent
Lias
Oolites (to top of Portlandian)
Numbers signify thicknesses in feet
By H. A BAKER, B.Sc., F.G.S

oolitic limestone with a pebbly base. With regard to the Bathonian, the record of the East Kent borings emphasizes Kendall's remark that "the unconformable overlap of the Great Oolite is one of the most marked features of Oolitic succession in Britain and in the north of France". The overlap of the Bathonian on the Palæozoic floor in East Kent occurs as a zone of N.W.–S.E. trend extending to northward of Stodmarsh and Woodnesborough. In tracing the isopachyte system of the East Kent Oolites the thicknesses[1] have been taken from the base of the Inferior Oolite to the top of the Portlandian, excluding the Purbeckian, since in the boring records the latter is sometimes not separated from the Wealden. Since it is only in the southern part of the area that Oolites higher than Corallian occur, there is no danger of arriving at erroneous conclusions in consequence of the omission of the Purbecks.[2] The Oolite isopachyte system proves very interesting (Map 2, Plate XXVII). We notice again the marked north-easterly thinning of the formation, with a strong tendency on the part of the isopachytes to assume a N.W.–S.E. alignment within the zone of influence of the easterly ridge. We also perceive once more an intimate relationship between the isopachytes and the pre-Upper Cretaceous contours of the Palæozoic floor. The effect of the Deal–Ropersole disturbance upon the isopachytes is very clear. There is, however, a particularly interesting and instructive feature presented by these isopachytes which appears to be missing from those of the Lias. In referring to the general character of the pre-Upper Cretaceous contours of the Palæozoic floor, mention has been made of the abrupt interruption, in the north, of the general north-westerly trend of the contours, and the suggestion has been put forward that this may be due to a movement (late Jurassic or early Cretaceous) of uplift in a new and discordant direction—in fact, roughly east and west. It will be noticed that in the north and west the Oolite isopachytes show a marked tendency to deviate southwards and to approximate to an E.–W. rather than a N.W.–S.E. direction. In the opinion of the present writer this southerly deviation of the Oolite isopachytes may be, in part, the result of denudation consequent upon the appearance of an east and west ridge of Oolitic rocks. It has long been known that such a ridge, extending westward beyond Streatham, existed in late Jurassic or early Cretaceous times, and was subjected to extensive denudation in Lower Greensand times and probably earlier. The writer regards this axis of uplift as one of Armorican affinity. The Oolitic ridge was partially submerged in Lower Greensand times and completely so during Gault times. The deep borings at Bobbing and Richmond showed the Lower Greensand resting on Oolites, while at Stodmarsh, Streatham, and Meux's Brewery the Oolites are directly succeeded by the Gault.

To the north-east of the feather-edge of the Oolites, there is an area, proved by the borings at Walmestone, Mattice Hill, and Ebbsfleet, where the Wealden overlap on the Palæozoic floor occurs. To

[1] See Table II, p. 403, at end of paper.

[2] In point of fact, the inclusion of the Purbecks still further emphasizes the north-easterly thinning of the Oolites.

the south-east of this area there is, in all probability, another where a Lower Greensand overlap occurs, since at Mattice Hill the Wealden is but 2 feet thick. In relation to the alleged easterly Charnian ridge, this area on the Kentish coast immediately to the south-east of the Mattice Hill boring is in parallelism with the boring at Culford in Essex, where the Lower Greensand overlap has been demonstrated. Doubtless, further south-east, beneath the waters of the Straits, there occurs an overlap of the Gault upon the Palæozoic floor in parallelism with the proved overlap at Harwich, Stutton, and Weeley.[1] On the south-easterly extension of the ridge, in North France, there occurs an area where an overlap of the Middle Chalk upon the Palæozoic floor exists. Apparently the ridge attained its greatest elevation to the south-east.

With regard to the isopachyte systems of the Cretaceous members of the Mesozoic cover, it is only to be expected that the intervention of a wedge-like mass of older Mesozoics, and the interference introduced by the Armorican movement, would mask to a large extent the relationship so readily traceable between the isopachytes of these older strata and the contours of the Palæozoic ridge. Nevertheless, in spite of these disturbing elements, it is still possible to perceive the influence of the ancient ridge.

In the opinion of the writer the South-East of England furnishes much evidence suggestive of Charnian posthumous movement, and that afforded by East Kent is a significant contribution.

TABLE I.

Boring.	Base of Gault referred to O.D.	Palæozoic Floor referred to O.D.	Palæozoic Floor when base of Gault is corrected to a datum-plane at O.D.
	Feet.	Feet.	Feet.
Chilham . .	−544	−1,022	− 478
Brabourne .	+149	−1,706	−1,855
Stodmarsh .	−931	− 979	− 48
Trapham .	−841	−1,065	− 224
Goodnestone .	−825	−1,052	− 227
Woodnesborough	−917	−1,021	− 104
Fredville . .	−689	−1,109	− 420
Barfreston .	−691	−1,027	− 336
Tilmanstone .	−711	− 943	− 232
Maydensole .	−641[2] (?)	− 941	− 300[2] (?)
Ripple . .	−722	− 814	− 92
Oxney . .	−696	− 859	− 163
Ropersole .	−553	−1,174	− 621
Waldershare .	−651	−1,069	− 418
Ellinge . .	−273	−1,211	− 938
Dover . .	−192	−1,108	− 916
Ebbsfleet . .	−995	−1,046	− 51
Mattice Hill .	−909	− 964	− 55
Walmestone .	−978	−1,001	− 23

[1] The Gault overlap has been proved in a deep boring at Calais.
[2] Estimated.

TABLE II.

Boring.	Thickness of Lias if present.	Thickness of Oolites, excluding Purbeck, if present.
		Feet.
Chilham	$23\frac{1}{2}$ feet	$412\frac{3}{4}$
Brabourne	140 ,,	1,020
Stodmarsh	? 5 ,,	43
Trapham	Absent	126
Goodnestone	Absent	142
Woodnesborough	Absent	30
Fredville	$10\frac{1}{2}$ feet	323
Barfreston	Absent	257
Tilmanstone	Absent	133
Maydensole	Absent	152
Ripple	Absent	? (less than 92)
Oxney	Absent	93
Ropersole	$21\frac{1}{2}$ feet	463
Waldershare	5 ,,	301
Ellinge	54 ,,	695
Dover	38 ,,	504
Ebbsfleet	Absent	Absent
Mattice Hill	Absent	Absent
Walmestone	Absent	Absent

IV.—ALBITE-GRANOPHYRE AND QUARTZ-PORPHYRY FROM BRANDY GILL, CARROCK FELL.

By ARTHUR HOLMES, A.R.C.S., D.Sc., F.G.S.

With an analysis by H. F. HARWOOD, M.Sc., Ph.D.

INTRODUCTION.

IN the course of an investigation into British resources of sands and rocks for glass-making and refractory purposes, which is being carried out by my colleague Dr. P. G. H. Boswell, it became desirable to search for an alumina-bearing siliceous rock low in iron-content. Among other rocks considered by Dr. Boswell was the granophyre of Brandy Gill, and a sample, obtained from Mr. W. Hemingway, was submitted to Dr. H. F. Harwood for analysis. So far as industry is concerned, the analysis indicates that the iron-percentage of the rock is too high for its use in glass manufacture. As such an analysis would be of interest and value to geologists—there being few first-class analyses of Lake District igneous rocks—and as it seemed undesirable that only a bare record should occur in a technological publication, Dr. Boswell handed to me the analysis and a sample of the granophyre, with the suggestion that the rock might be described in the pages of the GEOLOGICAL MAGAZINE.

I am indebted to Mr. Hemingway for two additional specimens of the rock, which occurs near the head of Brandy Gill, west of Carrock Fell. These specimens, though from practically the same locality as the granophyre, differ from it in having somewhat larger phenocrysts of quartz and albite and a more finely grained groundmass very nearly free from micrographic texture. They are therefore more accurately described as albite quartz-porphyry. Mr. Hemingway states that the rock was first noted in some mine workings near the head of Brandy Gill, where it was covered at the surface by a white decomposition product. The latter, which is known as "the china-clay bed" has been traced for more than a mile in a westerly direction. At Arye-stones the deposit is very extensive, but the fresh rock below was cut through by the old levels of the Roughten Gill lead-mines. At Brandy Gill the rock is penetrated by the tungsten veins of the Carrock mines, which carry scheelite and wulfenite.[1]

Petrography of the Albite Granophyre.

The granophyre of the Carrock Fell complex and its variations are well known from the description by Dr. Harker.[2] He describes the normal granophyre as showing[3] "small scattered crystals of black augite [diopside approaching hedenbergite] and white or glassy-looking oligoclase, in a fine-textured grey or cream-coloured or reddish groundmass". He then continues, "In some of the more acid examples the augite is wholly or almost wholly absent, and the rock has a white colour. This is the case at the head of Brandy Gill and in the peat moss south of Drygill Head, and the specific gravity of these specimens is naturally very low (2·578 and 2·530)."

The specimen analysed by Dr. Harwood is a white quartzite-like rock with sparsely distributed rectangular crystals of felspar which average about 3 mm. by 1 mm. in areal dimensions. The specific gravity is 2·63.

Under the microscope the felspar phenocrysts are seen to be dusky from incipient alteration, and to carry as inclusions small films and fans of muscovite. Albite, pericline, and carlsbad types of twinning are developed. A few cleavage flakes were obtained by crushing the rock, and the extinction angles (up to 19° on 010), mean refractive index (between 1·53, chlorobenzene, and 1·54, clove oil), and specific gravity (2·63 in a Klein solution of that density) indicate that the felspar is albite, a conclusion which is verified by the analysis.

The rock is crowded with small irregular crystals of quartz, often corroded, and varying regularly in size from undoubted phenocrysts to small masses that form part of the micrographic groundmass. The latter is of the finely textured type described by Harker,[4] with occasional felspar nuclei in optical continuity with that of the surrounding intergrowth. There are, however, numerous minute wisps of muscovite in the groundmass, and much of the felspar of the latter is altered to cloudy aggregates of sericite. Moreover, the rock contains here and there small fans of radiating muscovite with which zircon in well-crystallized prisms or rounded grains is invariably associated. No definite pyroxene has been

[1] For an account of similar veins in the Grainsgill greisen see A. M. Finlayson, Geol. Mag., Dec. V, Vol. VII, p. 19, 1910.
[2] "The Carrock Fell Granophyre": Q.J.G.S., li, p. 125, 1895 (Map of the Carrock Fell District, plate iv).
[3] Ibid., p. 131.
[4] Loc. cit., p. 128.

detected, but there are a few vague dark-green to black chloritic alteration products that may represent traces of a mafic mineral.

Sections show the presence of two kinds of microscopic veins, both being exceedingly thin and dying out within the limits of the section. The first of these consists of a quartz mosaic containing tiny specks of muscovite that twinkle like calcite over a rotating nicol. The second type of vein consists of dolomite and calcite, and is, as far as the evidence goes, later than the quartz type. The rock contains sufficient carbonate to effervesce with cold dilute acid when powdered. The analysis indicated that not all the carbonate could be calcite, and to test this point an uncovered section was prepared and treated with Lemberg's (logwood) solution. The greater part of the carbonate mineral failed to take the stain, thus confirming the presence of dolomite deduced from the analysis.

The chief accessory mineral seen in thin section in addition to those already mentioned is pyrite, though only two or three small cubic cross-sections have been seen in several slides. However, accessory minerals were also sought by the method adopted in the investigation of other Lake District granitic works by Messrs. Rastall and Wilcockson.[1] Some of the rock was crushed and a separation of the heavier particles was effected straight away with a Thoulet solution (potassium mercury iodide) having a specific gravity of about 3. A preliminary separation by panning was avoided because of shortage of material, and because of the paucity of heavy minerals, most of which would have been washed away by such a process. As soon as the crushed rock was stirred into the solution a few black grains could be seen falling through the white felsic constituents, and after a few minutes sufficient material was drawn off for examination. The magnetic portion, which was about a third of the whole, contained pyrrhotite with a little magnetite. This result is interesting in view of the universal occurrence of pyrrhotite in the other Lake District granitic rocks.[2] The residue (not picked up by a bar-magnet) consisted, in order of abundance, of pyrite, ilmenite, and zircon.

Chemical Analysis.

In calculating the mineral composition as given below, I have departed from the conventions of the *norm.* The norm would have shown figures for orthoclase and corundum. Corundum is certainly not present and orthoclase has not been detected, its place being taken by muscovite and sericite. For this reason the potash was expressed mineralogically as muscovite and the remaining alumina calculated as kaolin. As there is insufficient lime to satisfy all the carbon dioxide (and therefore none available for felspar) it was necessary to use some of the magnesia for this purpose, a procedure justified by the actual presence of dolomite in the rock. "Hypersthene" is probably the partial representation of the chloritic alteration products mentioned below.

[1] Q.J.G.S., lxxi, p. 592, 1915.
[2] Ibid., p. 617.

The following analysis of the Brandy Gill granophyre was made by Dr. H. F. Harwood:—

Percentages.		*Molecular Proportions.*	*Mineral Composition.*	
SiO_2 . . .	80·12	1·3353	Quartz . . .	53·57
Al_2O_3 . . .	10·68	·1047	Albite . . .	29·08
Fe_2O_3 . . .	0·06	·0004	Muscovite . .	12·12
FeO . . .	0·49	·0068	Kaolin . . .	1·00
MgO . . .	0·63	·0157		
CaO . . .	1·01	·0180	Hypersthene .	1·23
Na_2O . . .	3·44	·0555		
K_2O . . .	1·42	·0151	Magnetite . .	0·09
H_2O+ . .	0·80	·0444	Ilmenite . .	0·16
H_2O- . .	0·28	—	Pyrite . . .	0·17
CO_2 . . .	1·20	·0273		
TiO_2 . . .	0·09	·0011	Zircon . . .	0·04
P_2O_5 . . .	trace	—		
MnO . . .	0·05	·0007	Dolomite . .	1·66
S	0·09	·0028	Calcite . . .	0·90
BaO . . .	0·01	—		
ZrO_2 . . .	0·03	·0002	Water . . .	0·40
	100·40			100·42
Less O for S .	0·03		Less O for S .	0·03
Total .	100·37		Total .	100·39

The analysis is remarkable for the high percentage of silica that it reveals. The highest percentage found in the estimations made for Dr. Harker was 77·38, while in the specimen analysed by Mr. Barrow the silica amounted to 71·60 per cent.[1] The high alumina relative to alkalies has been interpreted above. The abundance of soda compared with potash justifies the name, *albite-granophyre*, applied to the rock.

Albite-Quartz-Porphyry.

The distinguishing features of this rock have already been stated above. The specimens are from one of those portions of the "granophyre" which "show little or no graphic structure at all, the quartz and felspar forming an irregular mosaic. In this case the quartz tends to occur partly in larger crystal-grains, and the rock approximates to some quartz-porphyries". To this description[2] there is little to add. The felspar is again albite, and quartz, which is very abundant, corrodes the felspar and is itself corroded by the groundmass. Muscovite occurs in larger wisps than in the granophyre, and also forms curious vermicular aggregates in the groundmass. As in the granophyre the rock contains narrow veins of quartz, and smaller ones containing carbonate minerals. The remaining minerals were determined by separation with Thoulet solution, using much more material than was available of the granophyre. The crop of heavy minerals proved to be identical with that obtained from the latter, except that in the residue remaining

[1] A. Harker, loc. cit., pp. 129–30.
[2] Harker, loc. cit., p. 128.

after treatment with a bar-magnet, a grain or two of brown tourmaline was also found. The specific gravity of both specimens is 2·63, the same figure as that for the granophyre.

Mr. Hemingway states that the rock is very similar to the white felsite interbedded in the Drygill shales to the north of Brandy Gill.

Geological Age.

It may be of interest to draw attention here to the recent work of Mr. J. F. N. Green on the age of the Carrock Fell complex.[1] It is well known that the complex is of later date than the Borrowdale volcanic series. An upper limit is fixed by Mr. Green's discovery of granophyre fragments in the Watch Hill Beds. These consist of shales and polygenetic grits which form a series of patches lying at various horizons on the Skiddaw Slates between Cockermouth (Watch Hill) and Great Sca Fell.[2] Only one pebble of granophyre was found at Watch Hill, but in the eastern exposures (i.e. in those near to Carrock Fell) the rock was found to be invariably present in the coarser bands of the series. Mr. Green shows that the Watch Hill Beds are younger than the Borrowdale Series and older than the Devonian earth-movements, and for these and other reasons he correlates them with the Coniston Limestone Series. Consequently he considers the igneous rocks of Carrock Fell to be pre-Bala. Mr. Green concludes: "The Borrowdale Series is ascribed to the Middle Llanvirn . . . The Eskdale granite, Buttermere granophyre, St. John's granite-porphyry, and Carrick Fell complex all belong to the suite, being intruded before the solfataric stage, but at a late period of the episode."

V.—The Fossils of the East Anglian Sub-Crag Boxstones.

By Alfred Bell.

In the opening article of the Geological Magazine (Vol. I, p. 5, 1864) Mr. J. W. Salter remarks: "An obscure but novel group of organic remains comes to light in some well-worked district for which we have as yet no fixed geological place," and this description may well apply to the fauna dealt with in the following pages.

Usually considered by geological writers as being derived from sources outside the East Anglian area, very little attention has been paid to it, its environment, or to its Continental affinities. The fossils hereafter referred to occur in a sandstone matrix[3] more or less consolidated, the relics of a former stratum afterwards broken up, and now found distributed in places beneath the overlying Pliocene deposits, between Walton-on-the-Naze and Hollesley on the coast and inland to about Ipswich.

[1] "The Age of the Chief Intrusions of the Lake District": Proc. Geol. Assoc., xxviii, pp. 17–25, 1917.

[2] Ibid., plate ii.

[3] An interesting and important paper dealing with the petrology of the Suffolk "Boxstones" (Crag), by Dr. P. G. H. Boswell, D.I.C., F.G.S. (now Professor of Geology in the University of Liverpool), appeared in the Geological Magazine for June, 1915 (pp. 250–9, Plate X, and Figs. 1–3) and may be consulted with advantage by readers of the present paper.

Within these boundaries the bed-rock is a floor of London Clay, formerly covered by a higher zone of the same material, replete with a fauna of similar type to that found at Sheppey, including fishes and Crustaceans in fine preservation, the broken-up clay and the fossils being deeply phosphatized. Upon this, again, there seems to have been deposited a bed of sand of which the actual presence can only be inferred, since it has not been found in situ as a separate stratigraphical unit or stratum; but the suggestion is warranted by the mass of debris yielding a particular group of fossils found in the irregular blocks of indurated sandstone or loosely distributed in the adjacent Crag sands, and in the tabular pieces present at Trimley, Bucklesham, and other places, of which Dr. J. E. Taylor writes in White's *History of Suffolk*, 1874, "that it is not uncommon to find slabs of the same kind of sandstone which appear to have undergone little abrasion and to be in nearly the same condition they were in when the formation to which they originally belonged was broken up." Similar pieces of sandstone with sharply defined impressions of the fossils and shells, more or less unworn, may be obtained occasionally during low tides at Bawdsey, where a bed of the nodules may be seen at times near the Haven.

The petrology of the "boxstones" has been fully described by Dr. Boswell, F.G.S.,[1] and the general features of the detritus by myself.[2]

In the discussion following the reading of Professor Lankester's paper[3] "On the Newer Tertiaries of Suffolk and their Fauna", Sir C. Lyell pronounced the boxstones then produced as being similar to those he had seen at Berchem, near Antwerp, in 1851,[4] in a deposit of Rupelien age, the shells corresponding to those figured by de Koninck in his well-known memoir[5] on the fossil shells of Basele, Boom, etc.

This particular horizon has been referred by M. van den Broeck[6] to the uppermost stage of the Middle Oligocene; a system largely developed, according to von Koenen, Ravn, and other writers, in Denmark, Belgium, and North-West Germany; with a few exceptions the boxstone species agree with those found in one or other of these localities.

The English literature bearing upon the deposit and the faunas associated with it before 1865 is very scanty. Charlesworth, in 1837, figured a tooth of *Carcharias megalodon*, with sundry notes on the phosphatic nodules; and the so-called "Coprolites" and mammalia recorded between then and 1851 are mentioned in the bibliography appended to C. Reid's *Pliocene Deposits of Great Britain* (1890). The earliest descriptive account[7] is that given by the Rev. W. B.

[1] "Petrology of the Suffolk Boxstones": op. cit.

[2] "Sub-Crag Detritus": Proc. Prehistoric Soc. East Anglia, 1915, vol. xi, pp. 139–48.

[3] Quart. Journ. Geol. Soc., vol. xxvi, pp. 493–513, 1870.

[4] Quart. Journ. Geol. Soc., vol. viii, p. 282, 1852.

[5] Mém. Acad. R. Sci. Bruxelles, vol. xi, 1837.

[6] Bull. Soc. Belge Géol., vol. vii, p. 299, 1893.

[7] Ann. Nat. Hist. (2), vol. viii, pp. 206–11, 1851.

Clarke, of Ipswich, on the nodule "bed" and its contents, figuring amongst other items a ziphioid rostrum. This was apparently reproduced with other species in an early paper on Red Crag Mammals,[1] by Professor Owen.

Mr. S. V. Wood was the first to recognize the shells in the boxstones,[2] specifying several of these by name, but nothing further was done till Professor Sir Ray Lankester, in 1865, briefly noticed the deposit and, in 1868,[3] discussed at some length its possible origin and that of its contents.

Unfortunately for science, the closing of the "Coprolite" industry or phosphate diggings, and the little interest taken in the stones when they were obtainable, limits the scope of our inquiry, and all that can be done is to utilize the material at hand. This is chiefly conserved in the Museums of Practical Geology, London, Ipswich, Norwich, and York, and in one or two private collections, all of which, by the courtesy of those in charge of them, it has been my privilege critically to examine. I have also to thank the Trustees of the Percy Sladen Memorial Fund for assistance in collecting information.

The specimens upon which the following lists are founded commonly occur as moulds of the exterior of the shells, showing the sculpture, or as casts of the interior; the shelly matter being rarely preserved. From these it has been possible by the use of wax or gutta-percha to reproduce the general details of the organism, which has been done by permission, from a number of the rarer and more perfect examples, especially those in the York and Norwich Museums. These will be ultimately added to those specimens already preserved in the Museum of Practical Geology, London.

The fossils are so scattered that it may be useful to students to know the Museums where they can be seen, and to have a reference to some good figure of the shell referred to in the text. As a rule the organisms have suffered little attrition, the sculptural details are well preserved, and most of the bivalves are found closed, as if embedded alive before the muscles had become relaxed.

Boxstone Mollusca.

Cylichna sp.

Cylichna cylindracea, Ravn, K. Danske Vid. Selsk. Skrift. (7), vol. iii, p. 367, pl. viii, fig. 15, 1907. Mus. Pract. Geol. London, York.

Ringicula auriculata, Menard.

Ringicula auriculata. Beyrich, Zeitsch. deutsch. Geol. Ges., vol. v, p. 330, pl. v, fig. 13, 1853. Mus. Pract. Geol. London.

Ringicula striata, Philippi.

Ringicula striata, Philippi, Beit. tert. N.W. Deutschl., p. 28, pl. iv, fig. 23, 1843.

,, ,, Ravn, K. Danske Vid. Selsk. Skrift. (7), vol. iii, p. 365, pl. viii, fig. 11, 1907.

Mus. Pract. Geol. London.

[1] Quart. Journ. Geol. Soc., vol. xii, 1856.
[2] Crag Moll., pt. ii, 1851.
[3] Geol. Mag., Vol. II, pp. 103–49, 1865; Vol. V, p. 254, 1868.

Conus Dujardini, Deshayes.

Conus Dujardini, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 40, pl. v, figs. 3–8, 1856.
,, ,, Lankester, Quart. Journ. Geol. Soc., vol. xxvi, p. 502, pl. xxxiv, fig. 5, 1870.
Mus. Ipswich, Norwich.

Conus antediluvianus, var. B, Grateloup.

Conus antediluvianus, var. B, Grateloup, Atlas Conch. foss. de l'Adour, No. 44, fig. 6, 1840. Mus. Ipswich, York.

Conus cf. *ventricosus*, Bronn.

Conus ventricosus, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 32, pl. iii, figs. 5–6, 1856.
,, ,, Fontannes, Moll. plioc. Vall. du Rhone, vol. i, p. 144, pl. viii, fig. 11, 1887.
Mus. Ipswich.

Pseudotoma Morreni, de Koninck.

Pleurotoma Morreni (de Koninck), Coq. foss. Basele, 1837, p. 21, pl. i, fig. 3. Mus. Ipswich.

[Mr. F. W. Harmer (Plioc. Moll. Gt. Brit., pt. ii, p. 212, regards this shell as a variety of *Pl. intorta*, Brocchi, with which it has many points of resemblance.]

Pleurotoma Steinvorthi, Semper.

Pleurotoma Steinvorthi, von Koenen, Mioc. nord-Deutschl., p. 94, pl. ii, fig. 10, 1872.
,, ,, Norregaard, Dansk. Geol. Foren., vol. v, p. 133, pl. iii, fig. 10, 1916.

Cancellaria (*Trigonostoma*) cf. *ampullacea* (Brocchi).

Voluta ampullacea, Brocchi, Conch. foss. Sub-ap., vol. ii, p. 313, pl. iii, fig. 9.
Trigonostoma ampullacea, Sacco, Moll. Tert. terz. Piem., pt. xvi, p. 9, pl. i, figs. 16–20.

[Some imperfect forms at Ipswich may belong to *C. umbilicaris*, Brocchi, but as the aperture is not seen in either species, both ascriptions may need revision.]

Cancellaria (*Ventrilia*) *aperta* (Beyrich).

Cancellaria aperta, Beyrich, Zeitsch. deutsch. Geol. Ges., vol. viii, p. 586, pl. xix, fig. 5, 1856. Mus. York.

Ancilla Nysti, F. W. Harmer.

Ancilla Nysti, F. W. Harmer, Plioc. Moll. Gt. Brit., pt. i, p. 52, pl. xii, figs. 32–3, 1913. Harmer Coll.

Voluta (*Pyrgomitra*) *fusus* (Philippi).

Fasciolaria fusus, Philippi, Beit. N.W. deutsch. tert., p. 25, pl. iv, fig. 14, 1843.
Voluta parca, Beyrich, Zeitsch. deutsch. Geol. Ges., vol. v, p. 357, pl. viii, fig. 1, 1853. Mus. York, Ipswich.

[These figures represent the younger and older states of the shell. It has a longer and narrower canal than the typical *V. Lamberti* of the Anglo-Belgian Crag basin. Dr. Mörch, in the Journ. de Conch., vol. xvii, p. 428, 1869, assigns this group to the sub-genus *Pyrgomitra*.]

Voluta (*Pyrgomitra*) sp.

Voluta cf. *tarbelliana*, var. *ventricosa*, Grateloup, Atlas Conch. foss. l'Adour, pl. xxxix, fig. 2, 1840.
Voluta auris-leporis, Lankester, Quart. Journ. Geol. Soc., vol. xxvi, p. 502, pl. xxxiv, fig. 6, 1870.
Mus. Ipswich.

Mitra cf. *fusiformis*, Brocchi.

Mitra fusiformis, Cerulli-Irelli, Pal. ital., vol. xvii, p. 235, pl. xxi, fig. 19, 1911. Mus. Pract. Geol., London.

[The reference is founded on the cast of a long body and next whorl, 60 mm. long, 25 mm. broad, with a nearly straight figure. *Mitra Venayssina*, Fontannes, Moll. Plioc. Vall. du Rhone, vol. i, p. 79, pl. vi, fig. 1, is closely allied to it.]

Sipho gregarius (Philippi), *pars.*

Fusus gregarius, Beyrich, Zeitsch. deutsch. Geol. Ges., vol. viii, p. 59, pl. v, figs. 7–8, 1856. Mus. Norwich, Ipswich.

Sipho lineatus (de Koninck).

Fusus lineatus, de Koninck, Coq. foss. Basele, p. 18, pl. iii, figs. 1, 2, 1837. Mus. Pract. Geol. London, Ipswich, York.

Sipho multisulcatus (Nyst).

Fusus multisulcatus, Nyst, Coq. foss. Belge, p. 494, pl. xl, fig. 1, 1843. Mus. Pract. Geol. London.

[Nyst altered de Koninck's specific name *lineatus* to *multisulcatus*, but his figure is not the same as de Koninck's, which shows a shell having a longer spire and canal, and narrower in proportion. They may be varieties of a polymorphous form, but as both varieties occur in the boxstones they are given accordingly for what they are worth.]

Sipho major, A. Bell.

Sipho major, A. Bell, Journ. Ipswich Field Club, vol. iii, p. 9, 1911.
Fusus erraticus, var., Harder, Danm. Geol. Undersøg., vol. ii, p. 83, pl. vi, fig. 31, 1913.

Mus. Ipswich.

[This is a large shell, the three lower whorls measuring 80 mm. in length with a breadth of 35 mm. This and the next species may perhaps represent a new group, intermediate between *Sipho* and *Fasciolaria*, as the moulds of the upper whorls show traces of costal ornament. Of this group *Fusus* (aff.) *Konincki*, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, pl. v, fig. 10, might be taken as the type.]

Sipho Ravni, sp. nov.

Fusus erraticus, var., Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 333, pl. vi, fig. 13, 1907. Mus. Pract. Geol. London, Norwich.

Fasciolaria (*Surculofusus*) *erraticus* (de Koninck).

Fusus erraticus, de Koninck, Coq. foss. Basele, p. 19, pl. ii, fig. 5, 1837.
,, ,, Nyst, Coq. foss. Belge, p. 496, pl. xl, fig. 2, 1843.
Mus. Pract. Geol. London, Ipswich.

Liomesus nudum (S. V. Wood).

Buccinum nudum, S. V. Wood, Mon. Crag Moll., Suppl. 2, p. 1, pl. i, fig. 1, 1879.

Liomesus ventrosus (Beyrich).

Fusus ventrosus, Beyrich, Zeitsch. deutsch. Geol. Ges., vol. viii, p. 35, pl. ii, figs. 3–5, 1856.
Buccinopsis Dalei, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 313, pl. v, fig. 1, 1907.

Moore and Stanley Coll.

[Many of the shells found in the Scaldisien beds in Belgium figured as *B. Dalei*, Sow., are much nearer to this species than to those in the English Crag. Fig. 4 in Beyrich's plate is an almost exact delineation of some of the Belgian forms.]

Liomesus cf. *danicus* (von Koenen).

Buccinopsis danicus, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 313, pl. iv, figs. 10–11, 1886. Mus. Pract. Geol., London.

[The shells figured by Ravn are both imperfect, and the London specimen is referred to it with some doubt as only the dorsal aspect is exposed. It is a rare shell on the Continent, as it is only recorded from the Danish Oligocenes.]

Cominella conica, sp. nov.

A smooth elongate bucciniform shell, channelled at the upper part of the volutions. Whorls 5–6, rounded and sub-carinated. Apex blunt. Aperture semilunate. Outer lip thickened, base but slightly prolonged. Umbilicus exposed by the loss of shelly matter. Height 35 mm., breadth 20 mm. Mus. Ipswich, Cambridge.

Desmoulea conglobata (Brocchi).

Buccinum conglobatum, Brocchi, Conch. foss. Subap., vol. i, p. 334, pl. iv, fig. 15, 1814.

Nassa conglobata, S. V. Wood, Mon. Crag Moll., pt. i, p. 32, pl. iii, fig. 9, 1848.

Mus. Pract. Geol. London, York, Ipswich.

Semicassis saburon (Bruguière).

Cassis saburon, Beyrich, Zeitsch. deutsch. Geol. Ges., vol. vi, p. 480, pl. xii, fig. 5, 1854.

Cassidaria sp., Lankester, Quart. Journ. Geol. Soc., vol. xxvi, p. 502, pl. xxxiv, fig. 8, 1870.

In most collections.

Echinophoria sulcosa (Lamarck).

Cassis sulcosa, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 179, pl. xv, fig. 8, 1856.

Cassidaria sp., Lankester, Quart. Journ. Geol. Soc., vol. xxvi, p. 502, pl. xxxiv, fig. 9, 1870.

Mus. Pract. Geol. London, Ipswich.

Echinophoria Rondeleti (Basterot).

Cassis Rondeleti, Basterot, Mém. Géol. sur les Env. de Bordeaux, p. 51, pl. iii, fig. 22; pl. iv, fig. 13, 1825.

Cassis Rondeleti, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 307, pl. iv, fig. 9, 1907.

Mus. Ipswich.

[The late Mr. C. Reid includes *Cassidaria bicatenata* in his list of Mollusca from the Suffolk boxstones. Plioc. Dep. of Britain, p. 13. It is probably a clerical error.]

Ficula acclinis (S. V. Wood).

Pyrula acclinis, S. V. Wood, Mon. Crag Moll., pt. ii, p. 311, pl. xxxi, fig. 6, 1850. In most collections.

[The most characteristic feature of this species is the great breadth of the upper part of the whorls. *Pyrula condita* in Hörnes' great work, vol. i, pl. xxviii, fig. 4, seems to agree with Wood's shell.]

Ficula cingulata (Bronn).

Pyrula cingulata, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 676, pl. xxviii, fig. 1, 1856 (figured as *P. reticulata*). Mus. Pract. Geol. London, York, Ipswich.

Ficula condita (Brongniart).

Pyrula condita, Brongniart, Mém. sur les Terr. du Vicentin, p. 75, pl. vi, fig. 4, 1823.

Pyrula reticulata, S. V. Wood, Mon. Crag Moll., pt. i, p. 42, pl. ii, fig. 12, 1848.

Mus. Pract. Geol. London, York, Ipswich.

Ficula cf. *geometra* (Borson).

Pyrula geometra, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 271, pl. xxviii, fig. 7, 8, 1856. Mus. Pract. Geol. London.

[A graceful cast in this museum may be assigned to this species with some uncertainty. In form and outline, however, it corresponds to Hörnes' and Sacco's figures of the shell.]

Pseudocassis sphærica (Philippi).

Cypræa spherica, Beyrich, Zeitsch. deutsch. geol. Ges., vol. v, p. 319, pl. iv, fig. 9, 1853. Mus. York.

[Mr. F. W. Harmer has in his collection a cast of a shell belonging to this group, having the inner whorls coiled on a flat plane round the apex as in some of the Conidæ, height 30 mm., breadth 20 mm., found at Waldringfield. For the genus see Fischer, Manuel de Conchyliologie, p. 668.]

Trivia pisolina (Lamarck).

Cypræa pisolina, Lamarck (Deshayes), Anim. sans Vertebr., 2nd ed., vol. vii, p. 408, 1822.

Trivia pisolina, F. W. Harmer, Plioc. Moll. Gt. Brit., pt. i, p. 50, pl. ii, fig. 17, 1913.

Moore Coll.

Rimella gracilenta (S. V. Wood).

Rostellaria (?) *gracilenta*, S. V. Wood, Mon. Crag Moll., Suppl. 3, p. 1, pl. i, fig. 1, 1882. Mus. Ipswich.

Rimella lucida (?), (S. V. Wood), J. Sowerby.

Rostellaria lucida (?), S. V. Wood, Mon. Crag Moll., Suppl. 1, pt. i, p. 5, pl. ii, fig. 14, 1872. Mus. Ipswich.

Rostellaria dentata, Grateloup.

Rostellaria dentata, Grateloup, Atlas Conch. foss. de l'Adour, No. 32, fig. 4, 1840.

,, ,, Cossmann, Ess. Paléoconch. compar., vol. vi, p. 19, pl. ii, fig. 12, 13, 1904.

Mus. Ipswich.

Hippochrenes ampla Rutoti, var. nov.

Rostellaria ampla, Rutot, Ann. Soc. malac. Belge, vol. xi, p. 33, pls. i, ii, 1874. Mus. Norwich (spire), Ipswich (body).

Aporrhais speciosus (Schlotheim).

Aporrhais speciosus, Beyrich, Zeitsch. deutsch. geol. Ges., vol. vi, p. 492, pl. xiv, figs. 1–3, 1854.

,, ,, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 302, pl. iii, fig. 24, 1907.

Mus. Ipswich.

Cerithium acuticosta angulatior, Sacco.

Cerithium acuticosta, var. *angulatior*, Sacco, Moll. Terr. terz. Piemonte, pt. xvii, p. 4, pl. i, fig. 6, 1895. Mus. Norwich.

Vermetus (*Burtinella*) *Bognoriensis*, Mantell.

Vermetus Bognoriensis (?), S. V. Wood, Mon. Crag Moll., pt. i, p. 114, pl. xii, fig. 9, 1848. Mus. Ipswich.

[This shell (or annelid) is commonly diffused in the loose sands of the older Red Crags, as well as in the hardened original matrix. S. V. Wood, Suppl. 3, p. 1.]

Vermilia flagelliformis (Morris).

Serpula flagelliformis, J. Sowerby, Min. Conch., vol. vii, p. 50, pl. DCXXXIV, figs. 2, 3, 1844. Attached to shell of *Pectunculus*. Mus. York.

Turritella Geinitzi, Speyer.

Turritella Geinitzi, Speyer, Palæontographica, vol. xvi, p. 22, pl. ii, fig. 2, 1866.
,, ,, Norregaard, Danske Geol. Forening, vol. v, p. 122, pl. iii, fig. 7, 1916.

Mus. Ipswich.

Xenophora Deshayesi (Michelotti).

Xenophora Deshayesi, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 442, pl. xliv, fig. 12, 1856.
,, ,, Sacco, Moll. Terr. terz. Piemonte, pt. xx, pl. ii, fig. 20, 1896.

Mus. Pract. Geol. London.

Xenophora scrutaria (Philippi).

Trochus scrutaria, Philippi, Beit. Tert. N.W. Deutschlands, p. 22, pl. iii, fig. 37, 1843.
Xenophoria scrutaria, Speyer, Palæontographica, vol. xvi, p. 328, pl. xxxiv, fig. 8, 1866.

Mus. Pract. Geol. London.

Natica achatensis (Recluz MS.), de Koninck.

Natica achatensis, de Koninck, Coq. foss. Basele, p. 9, 1837.
Natica glaucinoides, Nyst, Coq. foss. Belge, p. 442, pl. xxxvii, fig. 32, 1843.
Mus. Pract. Geol. London, York, Ipswich.

Natica Nysti, cf. D'Orbigny.

Natica Nysti, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 293, pl. iii, fig. 10, 1907. In most collections.

Natica cf. *hantoniensis*, Pilkington.

Natica hantoniensis, von Koenen, Palæontographica, vol. xvi, p. 148, pl. xii, fig. 9, 1867.
,, ,, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 290, pl. iii, fig. 6, 1907.

Mus. York.

[This fine cast, height 33 mm., breadth 25 mm., is clean from any adventitious matter. Its globose form and straightness of columella indicate its connection with the above species. Unfortunately the outer mould was not preserved.]

Natica (*Crommium*) *ferruginea italica* (Sacco).

Crommium ferrugineum italica, Sacco, Moll. Terr. terz. Piemonte, pt. ix, p. 8, pl. i, fig. 8, 1891. Mus. Pract. Geol. London, Ipswich.

Natica elongata, Michelotti.

Natica elongata, Michelotti, Et. Mioc. Inf. d'Italie, p. 88, pl. x, fig. 34, 1861.
Euspirocrommium elongatum, Sacco, Moll. Terr. terz. Piemonte, pt. ix, p. 10, pl. i, fig. 11, 1891.

Stanley Coll.

Niso sp.

[The cast referred to this genus exhibits the perforated axis very clearly, and is probably that of one of the many forms of *Niso* (*Bonellia*) *terebellata*, Grateloup, figured by Sacco, Moll. Terr. terz. Piemonte, pt. xi, pl. i, figs. 39–52. Harmer Coll.]

Bolma granosa miocenica, Sacco.

Bolma granosa miocenica, Sacco, Moll. Terr. terz. Piemonte, pt. xxi, p. 13, pl. i, fig. 28, 1896. Mus. Pract. Geol. London.

Phorcus striatus, Risso.

Phorcus striatus, Risso, Hist. Nat. Eur. merid., vol. iv, p. 134, 1826.

[Risso's diagnosis of this species, which he only knew as fossil, equally describes the boxstone shell, so as to render them practically identical. Mus. Ipswich.]

Calliostoma millegranus præcedens (von Koenen).

Trochus labarum (?), Basterot, Mém. Géol. de l'Env. de Bordeaux, 1825, p. 33, pl. i, fig. 23.

Trochus miliaris, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 454, pl. xlv, fig. 9, 1856.

Trochus millegranus præcedens, von Koenen, Mioc. N. Deutschlands (Marburg), p. 308, 1872.

Mus. Pract. Geol. London.

Calliostoma Xavieri (Costa MS.).

Trochus Xavieri, Dollfus, Cotter, & Gomes, Moll. tert. du Portugal, p. 6, pl. xxxi, fig. 4, 1903.

Zizyphinus opisthosthenus, cf. Fontannes, Moll. Plioc. de la Vall. du Rhone, vol. i, p. 218, p. xi, fig. 22, 1897.

Mus. Ipswich.

Dentalium sp.

(?) *Dentalium fossile*, Hörnes, Foss. Moll. Tert. Wien, vol. i, p. 657, pl. i, fig. 36, 1856. Stanley Coll.

Dentalium Kickxii, Nyst.

Dentalium Kickxii, Nyst, Coq. foss. Belge, p. 342, pl. xxxvi, fig. 1, 1843.

,, ,, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 286, pl. iii, fig. 4, 1907.

Mus. Pract. Geol. London.

Spondylus sp.

[The genus is represented by a perfect upper valve with the inner side exposed showing the characteristic dentition. It is recorded from the Belgian Oligocenes. See Vincent, Ann. Soc. malac. de Belge, vol. xxiii, 1888. Mus. York.]

Pecten (Chlamys) Malvinæ, Dubois de Montperoux.

Pecten Malvinæ, Dubois de Montperoux, Coq. foss. Wolhyma, p. 71, pl. viii, figs. 2–3, 1831.

,, ,, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 414, pl. lxiv, fig. 5, 1870.

Stanley Coll.

Pecten (Chlamys) Sollingensis, von Koenen.

Pecten Sollingensis, von Koenen, Palæontographica, vol. xvi, p. 228, pl. xxvi, figs. 7, 8, 1867.

,, ,, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 251, pl. i, fig. 1, 1907.

Mus. Pract. Geol. London.

Pecten (Chlamys) Hoeninghausii, Defrance.

Pecten Hoeninghausii, Nyst, Coq. foss. Belge, p. 286, pl. xxii, fig. 2, 1843.

Pecten disparatus, S. V. Wood, Mon. Crag Moll., Suppl. 3, p. 12, pl. i, fig. 17, 1882.

Stanley Coll., Brit. Mus. (Nat. Hist.) London.

Pecten (Chlamys) substriatus, D'Orbigny.

Pecten substriatus, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 408, pl. lxiv, fig., 1870. Harmer Coll.

Pecten (*Chlamys*) *rupeliensis* (von Koenen).

Pecten rupeliensis, von Koenen, Palæontographica, vol. xvi, p. 232, pl. xxvi, fig. 12, 1867. Mus. Pract. Geol. London, Stanley Coll.

Pecten (*Chlamys*) cf. *Erslevi*, Harder.

Pecten Erslevi, Harder, Danm. geol. Undersøg., vol. ii, p. 44, pl. iii, figs. 3, 4, 1913. Mus. Pract. Geol. London.

[A fragment in the M.P.G. seems to agree with Harder's figure.]

Pecten (*Peplum*) sp.

Pecten verrucopsis, de Gregorio, Ann. de Geol., pt. xiii, p. 26, pl. iv, figs. 89, 90, 1894.

Pecten clavatus, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 252, pl. i, fig. 2, 1907.

Mus. Pract. Geol. London.

[Of the two figures cited above, Gregorio's comes nearest to the M.P.G. fragment.]

Pecten (*Chlamys*) *excisus*, Bronn.

Chlamys excisus, Dollfus & Cotter, Moll. Tert. du Portugal, 1909, p. 77, pl. viii, figs. 5–9.

[I found a characteristic fragment of this species in Newbourne Crag pit.]

Hinnites crispus (Brocchi).

Hinnites crispus, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 10, pl. ii, fig. 1, 1897. Stanley Coll.

Pinna pectinata Brocchi (D'Orbigny).

Pinna Brocchi, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 372, pl. i, figs. 1, 2, 1870.

Pinna pectinata Brocchi, Sacco, Moll. Terr. terz. Piemonte, pt. xxv, p. 29, pl. viii, fig. 1, 1898.

Mus. York, Stanley Coll.

Mytilus corrugatus, Brongniart.

Mytilus corrugatus, Brongniart, Mém. sur les tert. du Vicentin, p. 78, pl. v, fig. 6, 1823. Stanley Coll.

Arcoperna sericea (Bronn).

Modiola sericea, Philippi, En. Moll. Sic., vol. i, p. 71, pl. v, fig. 14, 1836.

,, ,, S. V. Wood, Mon. Crag Moll., pt. ii, p. 61, pl. viii, fig. 3, 1850.

Mus. Ipswich.

Pectunculus Philippi, Deshayes.

Pectunculus pulvinatus, var., Philippi, Beit. N.W. deutsch. tert., p. 13, pl. ii, fig. 13, 1843.

Pectunculus Philippi, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 262, pl. i, fig. 17, 1907.

Mus. Ipswich.

Pectunculus Bormidianus, Mayer.

Pectunculus Bormidianus, Mayer, Foss. Mus. Zurich, pt. iii, p. 49, 1868.

Axinea Bormidiana, Sacco, Moll. Terr. terz. Piemonte, pt. xxvi, p. 37, pl. ix, figs. 11–15, 1898.

Mus. Norwich, etc.

Pectunculus inflatus (Brocchi).

Arca inflata, Brocchi, Conch. foss. Subap., p. 494, pl. xi, fig. 7, 1814.

Axinea inflata, Sacco, Moll. Terr. terz. Piemonte, pt. xxvi, p. 32, pl. viii, figs. 1–6, 1898.

In most collections.

[*Pectunculus pilosus* and *P. glycimeris* are amongst the commonest forms in the boxstones, and probably other members of this variable group are present.]

Nucula donaciformis, Harder.

Nucula donaciformis, Harder, Danm. geol. Undersøg., vol. ii, p. 49, pl. iii, fig. 10, 1913. Stanley Coll.

Nucula placentina, Lamarck.

Nucula placentina, Philippi, En. Moll. Sic., vol. i, p. 65, pl. v, fig. 7, 1836.
,, ,, Sacco, Moll. Terr. terz. Piemonte, pt. xxvi, p. 46, pl. x, figs. 35–40, 1898.

Mus. Ipswich.

Nucula Haesendonckii, Nyst & Westendorp.

Nucula Haesendonckii, Nyst, Coq. foss. Belge, 1843, p. 236, pl. xviii, fig. 5.

[Sir E. Ray Lankester informs me that he had identified this very distinct species in the collection of the late Dr. Taylor in Ipswich. Unfortunately the specimen has been lost sight of.]

Nucula turgens, S. V. Wood.

Nucula turgens, S. V. Wood, Mon. Crag Moll., Suppl. 2, p. 44, pl. v, fig 6, 1879. Mus. Brit. Nat. Hist., Wood Coll.

Leda Deshayesiana (Du Chastel Coll.).

Nucula Deshayesiana, Nyst, Coq. foss. Belge, p. 221, pl. xv, fig. 8, 1843.
Leda Deshayesiana, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 258, pl. i, figs. 7, 8, 1907.

Stanley Coll.

Venericardia antiquata rhomboidea (Brocchi).

Chama rhomboidea, Brocchi, Conch. foss. Subap., p. 523, pl. xii, fig. 16, 1814.
Cardita (*Glans*) *rhomboidea*, Cerulli-Irelli, Pal. ital., vol. xiii, p. 135, pl. xii, fig. 28, 1907.

Mus. York.

Astarte Henckeliusiana, Nyst.

Astarte Henckeliusiana, Nyst, Coq. foss. Belge, p. 154, pl. ix, fig. 4, 1843.
,, ,, von Koenen, Palæontographica, vol. xvi, p. 250, pl. xxix, fig. 7, 1867.

Mus. Pract. Geol. London.

Astarte Kickxii, Nyst.

Astarte Kickxii, Nyst, Coq. foss. Belge, p. 157, pl. x, fig. 3, 1843.
Astarte Kicksii, Ravn, K. Danske Vid. Selsk. Skrift (7), vol. iii, p. 268, pl. i, fig. 21, 1907.

Mus. Pract. Geol. London, Stanley Coll.

Astarte cf. *solidula*, Deshayes.

Astarte solidula tauroscalarata, Sacco, Moll. Terr. terz. Piemonte, pt. xxvii, p. 25, pl. vi, fig. 29, 1899. Mus. Pract. Geol. London.

[Length 18 mm., breadth 22 mm.; sculpture, 6 or 7 thick concentric ribs. The number of these vary according to Sacco's figures of *A. solidula.*]

Cardium cingulatum, Goldfuss.

Cardium cingulatum, Goldfuss, Petr. Germ., vol. ii, p. 222, pl. cxlv, fig. 4, 1838.
,, ,, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 177, pl. xxv, fig. 1, 1870.

Mus. York, Ipswich.

[*C. venustum*, Lamk., *non* S. V. Wood, and *C. umbonatum*, A. Bell, *non* Sowerby.]

Cardium Woolnoughi, sp. nov.

[The species here referred to is not rare, but does not appear to have been figured or described by any Continental writer. In shape it is roundly ovate, tumid, and nearly equilateral, garnished with twenty-five to thirty narrow rounded prominent ribs continued below the lower margin with rather wider interspaces. The surface is much decorticated, leaving four or five ridges marking probably stages of growth. Mus. Ipswich.]

Cardium subdecorticatum, A. Bell.

Cardium subdecorticatum, A. Bell, Journ. Ipswich Field Club, vol. iii, p. 9, 1911.
Cardium cf. *decorticatum tenellum*, S. V. Wood, Mon. Crag Moll., pt. ii, p. 159, pl. xiv, fig. 1*d*, 1850.

In most collections.

[The above shell is decorticated as in Wood's figure, but the ribs are more open = *C. decorticatum* of Lankester and Reid.]

Isocardia cor (Linné).

Isocardia cor, S. V. Wood, Mon. Crag Moll., pt. ii, p. 193, pl. xv, fig. 9, 1850.
,, ,, Forbes & Hanley, Brit. Moll., vol. i, p. 472, vol. iv, pl. xxxiv, fig. 2, 1853.

Mus. York, Ipswich.

Isocardia lunulata, Nyst.

Isocardia lunulata, Nyst, Coq. foss. Belge, p. 198, pl. xv, fig. 2, 1843.
,, ,, Lankester, Quart. Journ. Geol. Soc., vol. xxvi, p. 502, pl. xxxiv, fig. 10, 1870.

In all collections.

Cyprina tumida, Nyst.

Cyprina tumida, Nyst, Coq. foss. Belge, p. 148, pl. x, fig. 1, 1843.
Cyprina rustica (*tumida*), S. V. Wood, Mon. Crag Moll., pt. ii, p. 197, pl. xviii, fig. 1, 1850.

Mus. York.

Cyprina scutellaria (Lamarck).

Cyprina scutellaria, Nyst, Coq. foss. Belge, p. 145, pl. vii, fig. 5; pl. viii, fig. 1, 1843. In most collections.

Cyprina islandica æqualis (J. Sowerby).

Cyprina æqualis, Goldfuss, Petr. Germ., p. 236, pl. cxlviii, fig. 5, 1838.
Cyprina islandica, S. V. Wood, Mon. Crag Moll., pt. ii, p. 196, pl. xviii, figs. 2*a*, *b*, 1850.

Cyprina islandicoides, Lamarck.

Venus islandicoides, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 121, pl. xiii, fig. 2, 1870.
Amiantis islandicoides, Sacco, Moll. Tert. terz. Piemonte, pt. xxviii, p. 21, pl. v, figs. 1–4, 1900.

Meretrix chione, Linné.

Meretrix (*Callista*) *chione elongata*, Bucquoy, Dollfus, & Dautzenberg, Moll. du Roussillon, vol. ii, p. 328, pl. lii, fig. 10, 1893.
Meretrix (*Callista*) *chione*, Cerulli-Irelli, Pal. ital., vol. xiv, p. 43, pl. viii, figs. 9, 10, 1908.

Moore Coll.

[Major Moore has in his collection a fine mould of the interior of a shell, corresponding to the above, found at Waldringfield.]

Ventricola multilamella (Lamarck), var. *Boryi*, Deshayes.

Venus sp., Lankester, Quart. Journ. Geol. Soc., vol. xxvi, p. 502, pl. xxxiv, fig. 7, 1870.
Ventricola multilamella, *Boryi*, Sacco, Moll. Terr. terz. Piemonte, pt. xxviii, p. 31, pl. viii, fig. 9, 1900.

Mus. Ipswich, Stanley Coll.

[The "boxstone" mould so closely approximates to the shell figured by Sacco that it may be regarded as the same species; the more so because *V. multilamella* is somewhat variable in outline.]

Meretrix (*Callista*) *fragilis* (Münster).

Venus fragilis, Goldfuss, Petr. Germ., vol. ii, p. 247, pl. cxlviii, fig. 8, 1840.
Venus circularis, A. Bell, Journ. Ipswich Field Club, vol. iii, p. vii, 1911.

Mus. Ipswich.

Meretrix (*Callista*) *suborbicularis* (Goldfuss).

Venus suborbicularis, Goldfuss, Petr. Germ., vol. ii, p. 247, pl. cxlviii, fig. 7, 1840. Mus. Ipswich.

[The shell quoted or figured by Koninck, Nyst, Ravn, and other writers as *Venus* or *Meretrix incrassata*, Sow., does not seem to be the same as the English shell of that name.]

Tapes vetula (Basterot).

Venus vetula, Basterot, Mém. géol. sur les Env. de Bordeaux, p. 89, pl. vi, fig. 7, 1825.
Tapes vetulus, Dollfus & Dautzenberg, Mém. Soc. géol. France, vol. xiv, p. 176, pl. ii, figs. 1–6, 1906.

Mus. Pract. Geol. London.

Donax minutus, Bronn.

Donax minutus, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 4, pl. i, figs. 8, 9, 1901. Mus. Pract. Geol. London, Ipswich.

Solenocurtus Basteroti, Desmoulins.

Solenocurtus Basteroti, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 15, pl. iv, fig. 1, 1901.
,, ,, Dollfus, Cotter, & Gomes, Moll. tert. Portugal, p. 27, pl. i, figs. 7–10, 1903.

Mus. Pract. Geol. London.

Solen (*Ensis*) cf. *Rollei* (Hörnes).

Ensis Rollei, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 15, pl. i, fig. 14, 1870.
,, ,, Dollfus & Dautzenberg, Mém. Soc. géol. France, vol. x, p. 65, pl. ix, figs. 35–8, 1902.

Mus. Ipswich.

Mactra miocænica, Dollfus & Dautzenberg.

Mactra miocænica, Dollfus & Dautzenberg, Mém. Soc. géol. France, vol. xi, p. 109, pl. vi, figs. 10, 11, 1904. Mus. Pract. Geol. London, Ipswich.

[*M. podolica*, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 62, pl. vii, fig. 5, may be a variant of this species.]

Mactra triangula, Renier.

Mactra triangulata, S. V. Wood, Mon. Crag Moll., 1850, pt. ii, p. 325, pl. xxi, fig. 21. Stanley Coll.
Mactra trinacria, Speyer, Palæontographica, vol. xvi, p. 34, pl. iii, fig. 4, 1861. Mus. Pract. Geol. London, York.

[The principal difference between *M. triangulata* and *M. trinacria* seems to be that the latter forms a more equilateral triangle than the other. Both are probably related to the recent *M. elliptica*.]

Lutraria sanna, Basterot.

Lutraria sanna, Basterot, Mém. géol. sur les Env. de Bordeaux, p. 94, pl. vii, fig. 13, 1825.
,, ,, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 31, pl. viii, fig. 5, 1901.
Mus. Pract. Geol. London, Ipswich.

Lutraria ovalis, sp. nov.

Lutraria sanna, Hörnes, Foss. Moll. Tert. Wien, vol. ii, p. 56, pl. v, fig. 5, 1870.
,, ,, Dollfus, Cotter, & Gomes, Moll. tert. du Portugal, p. 30, pl. iv, fig. 4, 1903.

[Allied to *L. oblonga*, Chemnitz.]

Lutraria elliptica Jeffreysii, De Gregorio.

Lutraria elliptica Jeffreysi, De Gregorio, Boll. Soc. malac. ital., vol. x, p. 143.
Lutraria lutraria Jeffreysi, Cerulli-Irelli, Pal. ital., vol. xv, p. 143, pl. xv, fig. 9, 1909.
Mus. Pract. Geol. London, Norwich, Ipswich.

Corbulomya complanata, var. B, Nyst.

Corbulomya complanata, Nyst, Coq. foss. Belge, p. 59, pl. ii, fig. ii, 1843. Stanley Coll.

Panopæa Menardi, Deshayes.

Panopæa Menardi, Hörnes, Foss. Moll. tert. Wien, vol. ii, p. 29, pl. ii, figs. 1–3, 1870.
Glycimeris Menardi, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 43, pl. xii, fig. 4, 1901.
In most collections.

Panopæa declivis, Michelotti.

Lutraria declivis, Michelotti, Etud. Mioc. Inf. d'Ital., p. 57, pl. vi, fig. 1, 1861.
Glycimeris intermedia declivis, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 45, pl. x, fig. 6, 1901.
Mus. Pract. Geol. London.

Panopæa Gastaldi (Michelotti).

Panopæa Gastaldi, Michelotti, Etud. Mioc. Inf. d'Ital., p. 54, pl. v, fig. 10, 1861.
Glycimeris intermedia Gastaldi, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 45, pl. x, fig. 4, 1901. Mus. Ipswich.

Panopæa (?) *acutangula* (Michelotti).

Lutraria acutangula, Michelotti, Etud. Mioc. Inf. d'Ital., p. 57, pl. vi, fig. 2, 1861.
Glycimeris intermedia acutangula, Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 46, pl. xii, fig. 10, 1901.
Mus. Ipswich.

Cyrtodaria vagina (S. V. Wood).

Glycimeris angusta, S. V. Wood, Mon. Crag Moll., pt. ii, p. 291, pl. xxix, fig. 2, 1850. Mus. Pract. Geol. London.

[I do not think this to be the same shell as the *Glyc. angusta* of Nyst's memoir, pl. ii, fig. 1. The latter has a more pointed extremity. This I have had from the Red Crag. Mr. Stanley has a small shell in his sandstone collection from Bawdsey which may be the same.]

Lucina (*Dentilucina*) *Barrandei*, Mayer.

Lucina Barrandei, Mayer, Journ. de Conch., vol. xix, p. 340, pl. x, fig. 1, 1871.
Dentilucina Barrandei, var., Sacco, Moll. Terr. terz. Piemonte, pt. xxix, p. 83, pl. xix, figs. 7–9, 1901.
Lucina Canhami, A. Bell, Journ. Ipswich Field Club, vol. iii, p. 9, 1911.
Mus. Ipswich.

Syndosmya sp.

[Two or three species of this group are present in the "boxstones", possibly the *Erycina longicallis* and *E. similis*, figured in Philippi, En. Moll. Sic., vol. ii, pl. xiii, figs. 7, 8, but they are not sufficiently definite for accurate determination. Stanley Coll.]

Syndosmya prismatica (Montagu).

Ligula donaciformis, Nyst, Coq. terr. Belge, p. 92, pl. iv, fig. 9, 1843.
Abra prismatica, S. V. Wood, Mon. Crag Moll., pt. ii, p. 239, pl. xxii, fig. 13, 1850.
Mus. Pract. Geol. London, York.

Thracia ventricosa, Philippi.

Thracia ventricosa, Philippi, En. Moll. Sic., vol. ii, p. 17, figured in vol. i, pl. i, fig. 10 (as *T. pubescens*), 1844.
Thracia ventricosa, S. V. Wood, Mon. Crag Moll., Suppl. 2, p. 48, pl. v, fig. 3, 1879.
Mus. Ipswich.

Teredo borings in wood are not uncommon, but the shells have entirely disappeared.

[Certain shells of pre-Crag origin are found in the Oakleyan and Newbournian zones of the Red Crag, and as some of these also occur embedded in the boxstones they are presumably of the same age.

Most of these are figured by Mr. S. V. Wood in the Supplements to the Crag Mollusca, and by Mr. F. W. Harmer in the Monograph on the Pliocene Mollusca now in course of publication.

A few like the *Rimellæ*, *Serpulæ*, *Turritellæ*, and *Venericardia* occur in profusion, but as a rule the majority are single specimens, as in the following list:—

Borsonia suffolciensis.
Pleurotoma denticulata.
,, *interrupta.*
,, *nodifer.*
,, *plebeia.*
,, *Selysii.*
Cancellaria evulsa.
Ancillaria glandiformis.
Volutilithes luctatrix.
,, *nodosa.*
,, *suturalis.*
Mitra fusiformis (?).
Fusus abrasus.
,, *crispus.*
Purpura derivata.
Stenomphalus Weichmanni.
Triton connectens.
Ranella (?) *anglica.*
Semicassis saburon.
Rimella, two or three species.
Turritella, two or three species.
Solarium, two or three species.
Ostrea, two or more species.
Pecten Hœninghausii.
,, *Sollingensis.*
Venericardia, several varieties.
Lucina crassidens.

I have not seen any specimens of the typical *Voluta Lamberti* of the English or Belgian Crags, or of *Pyrula* (*Ficula*) *reticulata*, or *Cassidaria bicatenata* in the "boxstones". The latter, however, is said to occur sparingly in the "Sables noirs d'Anvers".

Voluta Lamberti, *Atractodon elegans*, and *Cassidaria bicatenata* are occasionally washed ashore on the coast, from Aldborough to Walton-on-the-Naze, derived from some deposit probably of Diestian or Anversian age. Mr. Harmer has in his collection a worn shell of the *V. Lamberti* group, showing distinctly broad and swollen ribs on the upper whorls obtained from the Felixstowe shore.

Very few invertebrate remains other than the Mollusca have been obtained in the East Anglian area. I have only noticed, or found recorded :—

Crustacea.

Cœloma sp. (? *rupeliense*, Strainer), and segments of a narrow lobster-like species.
Balanus inclusus (*fide* Lankester), *B. unguiformis.*

Radiata.

Cyphosoma tertiarium, Cotteau.
Diadema megastoma, A. Bell.
Solaster Reedi, n.sp.

[This unique example belongs to the Reed Collection in the York Museum. It exhibits the dorsal surface of a thick fleshy starfish, covered with bunches of short fasciculate spines scattered over the surface, as they are in the recent *S. furcifer.*

Mr. W. K. Spencer, F.G.S., has kindly furnished me with the following notes of dimensions: "Major radius 33 mm. (approx.), minor radius 13 mm., width of arm at base 14 mm., no. of arms six."]

Cœlenterata.

Flabellum cuneata, Goldfuss, and another species.
Solenastrea Prestwichii, Duncan.
Trochocyathus anglicus, Duncan.

Woods, fruits, and nuts are common in the Belgian Rupelien deposits, and our sub-Crags are rich in these. Mr. W. Carruthers told me many years ago that he had determined three Angiospermous Dicotyledons, one conifer, and two palms. Certain plants or fruits retain their forms when phosphatized both in exterior shape and internal structure, but whether these have any relations to either of the woods present is not yet known. Mus. Ipswich, Saffron Walden.

Amber has been obtained from the Cromer Forest Bed, and Mr. C. Reid has referred to a variety of spiders, insects, etc., in amber washed up on the East Anglian coast, Trans. Norfolk and Norwich Nat. Hist. Soc., vols. iii–v. Mr. A. H. Foord, F.G.S., in vol. v, p. 92, figures many of these, including bees, beetles, cockroaches, and spiders, submitted to, and partly named by, Mr. C. O. Waterhouse and the Rev. O. P. Cambridge. Whether of the same age as the above woods has yet to be determined.

NOTICES OF MEMOIRS.

I.—On Mammalian Bones from Excavations in the London District. By Arthur Smith Woodward, LL.D., F.R.S.[1]

In an area so long populated as the London district the surface deposits are naturally very varied, and those of the historic period contain remains not only of the indigenous fauna but also of man's accidental importations. Even so late as the twelfth century William Fitzstephen wrote that the woods close to the city were well stocked with game—"stags, fallow-deer, boars, and wild bulls." Their bones and teeth are often found, besides the remains of other animals, perhaps partly of somewhat earlier date, among which the beaver is especially interesting. Bones of the beaver are indeed so

[1] Abstract of a lecture delivered to the South-Eastern Union of Scientific Societies at Burlington House, London, on June 7, 1917.

abundant in the marsh deposits of the Lea Valley, Essex, that this animal probably had much to do with the extension of the swamps in that region. A good skeleton of a beaver was found in 1911 when excavating at the Royal Victoria and Albert Docks.

Until comparatively recent times much of the land now covered with houses was occupied by market gardens, which it was customary to ornament with trophies brought home by sailors. Among these may be specially mentioned the ribs and jaws of whales, which were erected as arches or made into seats, and disappeared by burial as soon as building operations began. Remains of the oxen, sheep, and pigs used for food were also often buried, and heaps of them have been found in some places, such as Moorfields. They should be collected with care when circumstances allow of their being dated, because it is interesting to determine the successive breeds which they represent. Exceptional accumulations of bones are sometimes puzzling and less easily explained than one which I saw in the mud filling a former pond at Earl's Court House when it was dismantled in 1884. Here lived the eminent surgeon John Hunter, who thus disposed of the remains of many of the carcases he dissected.

Below the very irregular surface deposits of London there are the old gravels, with associated sand, brick-earth, and peat, of Pleistocene age, occurring at different levels above the Thames, which laid them down before it had cut out the valley to its present depth. Excavations in these river terraces yield mammalian bones almost everywhere.

Sometimes a cold or Arctic fauna is met with. A fine large antler of reindeer and part of the frontlet of a bison were dug up in Buckingham Palace Road in 1891, and similar remains were again found associated at Twickenham in 1894. With the latter Dr. J. R. Leeson discovered a characteristic frontlet of the saiga antelope, which lives now only on the steppes to the east of the Volga. A still more Arctic animal, the musk-ox, is represented in the British Museum by fragments from Plumstead Marshes, Crayford, and Maidenhead. Remains of the mammoth (*Elephas primigenius*) occur abundantly, and some of the best specimens have been found at the bottom of the Thames deposits, directly on the London Clay. Several parts of the skeleton of a young mammoth were discovered thus in an excavation at Endsleigh Street, Bloomsbury, in 1892. More fragmentary remains of the same animal were dug up in 1903 and 1909 in a peaty bed on the London Clay beneath the *Daily Chronicle* office, Fleet Street, associated with very fine skulls of old and young individuals of the woolly rhinoceros (*Rhinoceros antiquitatis*), which were given to the British Museum by Mr. Frank Lloyd. More recently part of the humerus of a lion has been found in the same deposit.

Evidence of a warmer Pleistocene fauna occurs in several places, and the collection of bones and teeth obtained in 1879 from the foundations of Drummond's Bank, Charing Cross, may be mentioned in illustration. I am indebted to Mr. Charles Drummond and the Manager of the Bank for the opportunity of examining this collection, which is still preserved there. The lion is represented by three vertebræ, part of a sacrum, the middle piece of a humerus, and a calcaneum. There is a characteristic molar tooth of the southern elephant, *Elephas antiquus*, while three fragments of tusk and some portions of limb-bones may well belong to the same species. Two bases of shed antlers evidently represent the large extinct fallow deer, *Cervus browni*, and other bases of antlers are characteristic of *Cervus elaphus*. Numerous bovine limb-bones are very variable in size and proportions, and may belong either to *Bos primigenius* or to a *Bison*. Fragments of limb-bones of a small *Rhinoceros* are not specifically determinable. The absence of *Hippopotamus* is curious, but remains of this animal have been found not far away in Cockspur Street and beneath the Admiralty Offices.

In the London district, as in other parts of Southern England, there is thus some evidence that the typically warm and typically cold members of the Pleistocene mammalian fauna were not altogether contemporaneous.

II.—A Geological Theory of the Origin of Man.

Probable Relations of Climatic Change to the Origin of the Tertiary Ape-Man. By Professor Joseph Barrell. *The Scientific Monthly* (New York), vol. iv, pp. 16–26, 1917.

LAST year (Bull. Geol. Soc. America, vol. xxvii, pp. 387–436) Professor Barrell pointed out that recurrent periods of semi-arid conditions might have had much influence on the evolution of vertebrate animals. As a dry season advanced, rivers would be reduced in flow, stagnant pools would result, and any fishes which endured these changed conditions would have to become much modified. The primitive sharks, for instance, found in the earliest Palæozoic freshwaters, having no air-bladder, would be driven to the seas. The freshwater fishes which remained were ganoids and dipnoans, with an air-bladder efficient for the direct use of air. From the crossopterygian ganoids, under the stimulus of the semi-aridity of the Devonian period, there arose the amphibians capable of existing as land animals; and so on.

The question now arises as to whether a similar climatic change in the Tertiary period, acting on species of large-brained and progressive anthropoid apes, isolated from forest regions, might not cause them to advance and become adapted for life on plains or die out. Professor Barrell thinks it would be so, and mentions that at the close of the Miocene period climatic conditions were such that this latest evolution may actually have occurred. There were at that time numerous apes in the warm forests south of the Himalayan region. As the mountains rose and the temperature was lowered some of the apes may have been trapped to the north of this area. As comparatively dry plains took the place of forests, and as the apes could no longer migrate southwards, those that survived must have become adapted for living on the ground and acquired carnivorous instead of frugivorous habits. The Miocene or early Pliocene ape-man may therefore be more hopefully sought in deposits of the open and temperate regions of Central Asia than in the alluvial deposits of the more southern tropical forests.

III.—Glastonbury Lake-Village.

The second volume of Messrs. Bulleid & Gray's report on the Glastonbury Lake-Village is just published. It is most valuable, and reflects the highest credit on the authors. This volume contains much matter of geological interest in addition to the archæology. There are reports on the plants by Clement Reid, on the bird remains by C. W. Andrews, on the wild and domestic mammalia by W. B. Dawkins & J. W. Jackson, and on the humans by W. B. Dawkins. The illustrations are profuse and excellent, and the report as a whole is as complete an account of such a site as has yet been made available.

Among the vertebrates the bird *Pelecanus crispus* is the most interesting, for although remains have been previously found in the Fens, Dr. Andrews has examined portions of five individuals and many fragments from Glastonbury, clearly indicating that the birds bred in the neighbourhood, and possibly pointing to a source of food for the inhabitants. The report closes with an exhaustive index, most wisely provided, which greatly enhances its value.

REVIEWS.

I.—Microscopical Determination of the Opaque Minerals. By Joseph Murdoch. pp. viii + 165, with 9 figures in the text and 1 coloured plate. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1916. Price 9*s*. 6*d*. net.

Why the microscope, while holding so predominant a position in the determination of rocks by means of the characters revealed in a thin slice and in the study of transparent substances generally, has hitherto been so little used in the study of metals and alloys and in the identification of opaque substances, is perhaps not difficult to understand. It is not at first sight by any means obvious that this instrument is at all suitable for the purpose, and so vast was the vista opened out by the application of the microscopical method to petrological work that the equally important field of research lying fallow in the case of opaque substances for a long time almost entirely escaped notice. It was, in fact, not till the discovery of different kinds of hardened steels and the consequent necessity for determining and explaining their various characteristics that metallurgists began to pay general attention to the microscopic study of polished sections. Yet more than half a century has elapsed since the gifted Sorby, to whom we are likewise indebted for drawing general attention to the advantage of the microscopic study of thin slices of rocks, had made use of practically all the devices in vogue among metallurgists of to-day; while it is only within the past four or five years that anything like a systematic study of the opaque minerals has been attempted. Mr. Murdoch's book marks the beginning of a new epoch. Previous writers and workers had confined their attention to some particular mineral group or some isolated problem. He is the first to make a systematic study of the opaque minerals, and above all to think out and develop a scheme for identifying them by the characters revealed under the microscope.

After a full historical account of the work of previous writers—not a great number—the author carefully describes the comparatively simple apparatus required for the preparation of suitable polished sections, and gives a list of the reagents which are used in microchemical work. The opaque minerals are divided into three main groups: coloured, white, grey. Difference in hardness as compared with a steel needle and the behaviour when treated with certain reagents are made use of for further subdivisions until the mineral species in question is finally run down. The white group is a large one, and for subdivision reliance is placed upon the tint as compared with the standard white of galena. Mr. Murdoch asserts that after a little practice the eye can unerringly appreciate such slight differences as greyish white, pinkish white, bluish white, and creamy white. A correct determination at this stage is important, since otherwise much time may be lost in following a false trail. The arrangement of the copious tables is the most remarkable feature of the book. By an ingenious use of cutting or "tabbing" the upper and side edges of the leaves reference to the tables is rendered easy, and to prevent mistakes the order of the tests is printed on the upper left-hand corner of the left-hand page.

This is, in short, a book that should be in the hands of every metallurgist or mineralogist.

II.—The Economic Geology of the Central Coalfield of Scotland. Description of Area V (Glasgow East, Chryston, Glenboig, and Airdrie). Mem. Geol. Survey Scotland. pp. viii + 146, with 13 plates and 5 figures. 1916. Price 4*s.* 6*d.*

THIS memoir is the first to be published of a series intended to provide a description of the economic geology of the central coalfield of Scotland. The area dealt with includes a large part of the city of Glasgow, and extends eastwards beyond Airdrie, with a tongue projecting beyond Longriggend into Linlithgowshire. The strata included all belong to the Carboniferous system, overlain in places by a considerable thickness of superficial deposits, both glacial and post-glacial, and there are a good many intrusive sills and dykes of dolerite, often containing analcime. As is well known, coal is largely developed in Scotland in the Lower Carboniferous, while the upper part of the Upper division is barren.

The memoir contains a detailed description of the coal-bearing strata of the district, again subdivided into four areas. This information is very largely derived from the records of mine-shafts and borings. From the manner in which it is presented it is evident that the memoir is intended mainly for the "practical man", since these portions are written in a language unintelligible to the ordinary scientific geologist. Among the descriptive petrological terms we find for example: stone, rib, metal, fakes, blaes, sclit, and daugh, without any explanation, while from the context it can be gathered that in the local patois "float" means a sill.

In spite of this drawback it is evident that the memoir contains a vast store of information which in this collected form must be of the utmost value to those concerned with the purely economic side of the subject. The dominant geological structures and the disposition of the principal faults and folds are clearly brought out, and there is also a brief but interesting chapter on the value of fossils, illustrated by two good plates, one of marine and freshwater shells, admirably drawn by Dr. Peach, and the other of some photographs of characteristic Coal-measure plants, contributed by Dr. Kidston. There are also some useful tables of analyses and physical data connected with fire-clay, which is largely developed in the district.

R. H. Rastall.

III.—Western Australia. Annual Progress Report of the Geological Survey for the year 1915, with an Index Map. Folio; pp. 44. Perth, 1916.

THIS work contains the following reports:—

1. The Building Stones of Western Australia, by H. P. Woodward, which includes a scheduled list of the Acid Igneous Rocks.
2. The Limestone Deposits near Denmark, by H. P. Woodward, with analyses by E. S. Simpson.
3. The Foraminiferal Sand Deposits of Dongara, by H. P. Woodward, with tabulated analyses and tests by E. S. Simpson.
4. The Commercial Application of the Dongara Foraminiferal Sands, by E. S. Simpson.
5. The Limestone Deposits of the Geraldton Districts, by H. P. Woodward, with chemical reports by E. S. Simpson.
6. Supplementary Report on the Limestone Deposits at Yonga (Martyup), by H. P. Woodward.
7. Yilgarn Goldfield, by T. Blatchford.
8. Kookynie and Tampa, by J. T. Jutson.
9. Albany, by J. T. Jutson and E. S. Simpson.
10. The Reported Occurrence of Oil near Wonnerup, South-West Division, by E. de C. Clarke, with an appendix by E. S. Simpson "On Samples of supposed Petroleum-bearing Earths and Water from Wonnerup".
11. Meekatharra, by E. de C. Clarke, with notices of the Acid, Basic, and Metamorphic Rocks of this district.
12. The North End (Kalgoorlie), by F. R. Feldtmann. Contains a detailed classification of the rocks of this region based upon the petrological examination of many specimens.
13. The Magnesite Deposit at Bulong, North-East Coolgardie Goldfield, by F. R. Feldtmann.
14. Geological Report on the Canning River Dam Site, No. 2, by F. R. Feldtmann.
15. The Occurrence of Gold at North Dandalup, by C. S. Houman.
16. Yerilla District, by C. S. Houman.

IV.—Western Australia. Geological Survey, Bulletin No. 63. The Geology and Mineral Resources of the Yilgarn Goldfield. Part II: The Gold Belt south of Southern Cross. By T. Blatchford, B.A., Assistant Geologist, with Petrological Notes by R. A. Farquharson, M.A. (Oxon.), etc., and Mineralogical Contributions by E. S. Simpson, B.E., etc., and A. J. Robertson, M.Sc. Issued under the authority of the Hon. P. Collier, M.L.A., Minister of Mines. pp. 189, with nineteen plates (maps and plans) and thirty-one figures (views showing geological phenomena, etc. Perth, 1915.

THE reports of this Bulletin are regarded as of great importance, since no detailed geological work has been previously published on the southern portion of the Yilgarn Goldfield. The Government Geologist, Mr. A. Gibb Maitland, regards this work as "a notable contribution to the geology of the portion of the State's goldfields of which it treats".

V.—Western Australia. Geological Survey, Bulletin No. 66. The Geology of the Country to the South of Kalgoorlie (Coolgardie and East Coolgardie Goldfields), including the Mining Centres of Golden Ridge and Feysville. By C. Sidney Houman, B.M.E. (Melb.), Field Geologist. Issued under the authority of the Hon. P. Collier, M.L.A., Minister for Mines. pp. 75, with nine plates (maps, sections, etc.) and seventeen figures (plans, sections, etc.). Perth, 1916.

IN a prefatory note the Government Geologist, Mr. A. Gibb Maitland, mentions that this report contains the results of an examination of about 700 square miles of country in portions of the Coolgardie and East Coolgardie Goldfields, lying to the south of Kalgoorlie and coterminous with that described in Bulletin 56.

VI.—A Bibliography of Fishes.

A Bibliography of Fishes, by Bashford Dean and C. R. Eastman, Amer. Mus. Nat. Hist., 1916, has just reached us, that is to say vol. i, containing author titles A–K, which alone occupy 718 pages in double column.

This work deals with fishes broadly (including Cyclestomes and *Amphioxus*), their habits, structure, development, physiology, pathology, distribution, and kinds. It does *not* include detailed references to species, genera, or even, in many cases, families. Nor does it treat of the vast economic interests of the group. These matters would entail years of labour and many volumes of additional print.

Vol. ii will conclude the author titles, and vol. iii will list up anonymous works, pre-Linnæan works, bibliographies, voyages and expeditions, special periodicals, and a complete index of subjects.

The collection of the material commenced in 1890, by 1900 had reached 20,000 cards, and now numbers 40,000 titles. Dean, Eastman, Hussakoff, v. Kupffer, A. Boehm, L. Neumayer, Brown, Goode, and F. J. Cole, all contributed to its preparation, aided by a staff of women clerks, and even thus thirty years have almost slipped away. Our thanks go out to all these workers.

It is only by these combined labours that work will be possible in the future. Indeed, it might be well if some encouragement were offered to those who devote themselves to compilations which quarter the work of the specialist, but are often the object of his indifference, and which (*crede experto*) he is sometimes too lazy even to use.

VII.—Tibetan Palæontology.

Le Crétacé et l'Eocène du Tibet Central. By Professor Henri Douvillé. Palæontologia Indica, 1916, new series, vol. v, Memoir No. 3, pp. 1–46, pls. i–xvi. Appendix by M. L. Morellet: Note sur les Algues Siphonées Verticillées, pp. 47–9, text-figures. Price 4 rupees, or 5*s*. 4*d*.

THIS memoir is descriptive of a collection of fossils obtained by the Tibetan Frontier Mission of 1903–4, under Colonel Sir F. E. Younghusband, of which Mr. H. H. Hayden (the present Director of the Geological Survey of India) was the Geologist in charge. Mr. Hayden has already published two important memoirs on the geological results of the expedition (Records Geol. Surv. India, vol. xxxii, pp. 160–74, pl. vii = geological map, 1905, and Mem. Geol. Surv. India, vol. xxxvi, pt. ii, pp. 122–201, with plates, sections, views, and map, 1907), in which a good general account is given of the specimens collected, together with the different horizons which they indicated.

The stratigraphy of the region as therein explained is briefly as follows: Supposed Palæozoic rocks, without fossils, in the Khonbu Valley; Trias (?), east of Dothak, with indeterminable Pelecypoda; Jurassic at Tsang and Ü, containing *Trigonia*, *Harpoceras*, etc.; Spiti Shales with characteristic Ammonites at Kampa Dzong; while Cretaceous and Tertiary formations, grouped as the "Kampa Series", were developed at Kampa Dzong and Tuna, from which the chief fossils were obtained. The Kampa Series being highly fossiliferous enabled Mr. Hayden to divide its Cretaceous portion into the Cenomanian, Turonian, Senonian, and Maestrichtian stages, the Tertiary being regarded as Eocene and the equivalent of the Lower Ranikot deposits of Western Sind, chiefly on account of the presence of what was determined as *Velates schmideliana*.

As a resumé of Hayden's researches further valuable remarks on the Cretaceous and Eocene stratigraphy of this region were made by Mr. Vredenburg in his paper on the Cretaceous Orbitoides of India (Records Geol. Surv. India, vol. xxxvi, pp. 186–90, 1908). From an examination of the fossils he was of opinion that the Tibetan Cretaceous sequence resembled that of Baluchistan, Persia, and Southern India, and that the Eocene corresponded with the Lutetian of Europe and the Laki group of India.

The present monograph deals exclusively with the palæontology of the "Kampa Series" (named after Kampa Dzong, nearly 200 miles south-west of Lhasa), several of Hayden's determinations being preserved, while others have been revised and added to in consequence of a more complete study of the fauna. A later stage is recognized among the Cretaceous rocks, viz. the Danian, in which is included *Velates tibeticus*, n.sp., a Gasteropod presenting considerable differences of form from the well-known *V. schmideliana* of older Eocene times, with which it had been confused by Hayden. A special chapter is devoted to the Orbitoides of the collection, which were recognized as belonging to the Campanian, Maestrichtian, and Danian, full acknowledgment being given to Mr. Vredenburg's important memoir on *The Cretaceous Orbitoides of India* previously referred to. The Eocene beds, having yielded *Alveolina*, *Orbitolites*, etc., are regarded as *Eocène inférieur*, but older than the Ranikot Beds of India. The author admits a continuity of deposits from Cretaceous times, a fact suggested by Hayden, who was unable to trace the existence of any unconformity between the Cretaceous and Tertiary—such a conclusion, we think, being also supported by reason of the absence of Nummulites in those rocks. For a better appreciation of the entire fauna the following list of its species and those of the Algæ, now described and mostly figured, is here appended:—

Cenomanian: *Acanthoceras newboldi*, Kossmat; *Mantelliceras laticlavium* (Sharpe); *M. discoidale* (Kossmat); *Turrilites costatus*, Lamarck; *T. wiestii*, Sharpe; *T. desnoyersi*, Orbigny. **Turonian** (?): *Inoceramus* sp.; ? *Plicatula radiola*, Lamarck; *Pycnodonta vesiculosa* (J. Sowerby). **Emscherian**: *Pycnodonta*. **Campanian**: *Actæonella crassa* (Dujardin); *Bournonia haydeni*, n.sp.; *B. tibetica*, n.sp.; *Endocostea haydeni*, n.sp.; *Lima* sp.; *Pycnodonta vesicularis* (Lamarck). **Maestrichtian**: *Nerinea ganesha*, Noetling; *Plagioptychus tibeticus* n.sp.; *Plicatula hirsuta*, Coquand; *Kingena heberti* (Orbigny); *Cymopolia tibetica*, n.sp. **Danian**: *Nautilus pseudobouchardi*, Spengler; *N.* cf. *rota*, Stoliczka; *Gisortia depressa* (J. de C. Sowerby); *Ovula* cf. *ellipsoides*, Archiac & Haime; *O.* sp.; *Terebellum distortum*, Archiac & Haime; *Gosavia salsensis* (Archiac & Haime); *Lyria* sp.; *Chenopus tibeticus*; *C.* (*Hippochrene*) *columbarius* (Lamarck ?), Archiac and Haime; *Drepanochilus fusoides* (Archiac); *Campanile* cf. *breve*, H. Douvillé; *C. brevius*, n.sp.; *Natica* cf. *flemingi*, Archiac & Haime; *Velates tibeticus*, n.sp.; *Venericardia*; *Corbis* cf. *lamellosa*, Lamarck; *Lima squamifera*, Goldfuss; *Chama* cf. *distans*, Deshayes; *Spondylus rouaulti*, Archiac; *Delheidia haydeni*, n.sp.; *Orbitoides vredenburgi*, n.sp.; *O. media*, Archiac; *O. tenuistriata*, Vredenburg; *Lepidorbitoides socialis* (Leymerie); *L. tibetica*, n.sp.; *L. polygonalis*, n.sp.; *Omphalocyclus macropora* (Lamarck); *Operculina canalis*, Archiac; *O. hardiei* (Archiac & Haime); *Siderolites miscella* (Archiac & Haime). **Eocene**: *Coniscala tibetica*, n.sp.; *Vulsellopsis legumen* (Archiac & Haime); *Liostrea flemingi* (Archiac & Haime); *Alveolina oblonga*, Orbigny; *Orbitolites complanatus*.

We must congratulate Professor Douvillé on the production of so excellent a work, more especially as we are given to understand that it was difficult of achievement on account of the bad preservation of the fossils. All palæontologists interested in the geology of this remote and little-known region of Asia will welcome so important and valuable a contribution to the literature of that subject.

R. B. N.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

June 19.—W. Barlow, F.R.S., President, in the Chair.

Dr. G. F. Herbert Smith: On the Problem of Sartorite. The examination of crystals kindly supplied for the purpose by Dr. C. O. Trechmann and Mr. R. H. Solly showed that the faces fall into zones which are only partially congruent. Just as in the case of calaverite earlier investigated by the author, there appear to be simultaneously in certain of the crystals five distinct lattices. The vertical spacing and the relative positions of the vertical planes remain unchanged, but in passing from the central lattice to the two lying on either side there is a distinct shear which varies in direction, though apparently not in amount, from crystal to crystal.

Dr. A. Scott: Note on a Curious Case of Devitrification. The glass of an old bottle found in river sand about four feet below the surface in Leven Shipyard, Dumbarton, has become almost completely crystallized. The crystals, which have a composition corresponding nearly to $2CaO . Na_2O . 5SiO_2$, are accompanied by some dark-coloured microlites. A piece of a glass which by accident had been allowed to cool slowly showed the same crystals and microlites, and in addition a few small needles with high refraction and large birefringence.

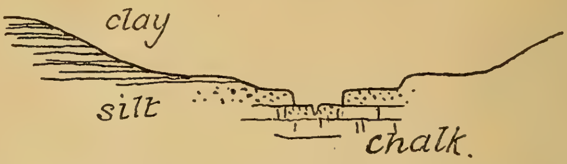
Dr. G. T. Prior: The Meteorites of Simondium, Eagle Station, and Amana. The results of analyses showed that the Amana stone belonged to the cronstadt, with some approach to the baroti type; that Eagle Station is an exception to other pallasites in containing iron richer in nickel and olivine correspondingly richer in ferrous oxide; and that Simondium was closer to the grahamites than to the howardites, since like other grahamites it contained nickeliferous iron and olivine in chemical composition similar to those of the pallasites, but with pyroxene and anorthic felspar similar to those of the howardites and eucrites.

CORRESPONDENCE.

FROM THE FRONT.

Dear Dr. Woodward,—I have by no means forgotten your kind letters, but I have not been in a position to write to you of late. The business in the Artillery line has been far too brisk to allow me quiet to get any correspondence done. Fortunately for me, the other night I did not retire to rest at my usual time, for my "dug-out" fell in and buried my "kit" under 8 foot of earth, so I cannot grumble at my luck, even though I have been out here now nine months without any leave.

Strangely enough, the fall of my "dug-out" brought out a rather interesting little geological section: a pocket of chalk about a foot in greatest diameter, with streaks running out of it for about 2 feet in one direction only, was exposed in the sandy cliff, though the solid chalk below had still another 15 feet of sand separating it from this pocket. The other day also I came across the finest illustration of a dried-up river-valley that I have yet seen. The terraces were distinct, the last level of deposition of silt being very pronounced. The layer of chalk exposed was only 4 inches thick, being covered elsewhere by silt at the bed of the river and with clay higher up.



This is the way I amuse myself in odd moments when dodging Hun shells and encouraging destruction on the part of our own.

E. W. H.

SIEGE BATTERY,
SOMEWHERE IN FRANCE.
June 7, 1917.

OBITUARY.

PROFESSOR WILLIAM BULLOCK CLARK,
A.B., PH.D., LL.D., FOR. CORR. GEOL. SOC. LOND.

BORN DECEMBER 15, 1860. DIED JULY 27, 1917.

PROFESSOR WILLIAM BULLOCK CLARK, A.B., Ph.D., LL.D., head of the Department of Geology in the Johns Hopkins University and Director of the Maryland Geological Survey from its organization in 1896, died suddenly on July 27, 1917.

Professor Clark was born in Vermont on December 15, 1860. In his earlier years he was an active student of invertebrate palæontology, especially of the Echinoidea. In later years he attained his great influence largely as an organizer of research. He was a Foreign Correspondent of the Geological Society of London, a member of the National Academy of Sciences, Treasurer of the Geological Society of America, President of the Association of American State Geologists, and a member of many other learned societies both at home and abroad. At the time of his death he was actively engaged as chairman of the Committee on Highways and Natural Resources of the Maryland Council of Defence, and of two sub-committees of the National Council of Defence.

MISCELLANEOUS.

GEOLOGICAL CHAIR IN LIVERPOOL UNIVERSITY.—We are glad to learn that Dr. P. G. H. Boswell, F.G.S., Assoc. R.C.S., D.I.C., of the Imperial College of Science, South Kensington, London, S.W., has been selected as Professor to fill the recently founded Herdman Chair of Geology in the Liverpool University.

EARTHQUAKE AND TIDAL WAVE, SAMOA.—A dispatch received at Melbourne from Suva states that a severe earthquake and a tidal wave have caused damage to the Samoa group of islands. An earthquake has been experienced in the Friendly Islands.

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ASSISTED BY

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DR. GEORGE J. HINDE, F.R.S., F.G.S.
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OCTOBER, 1917.

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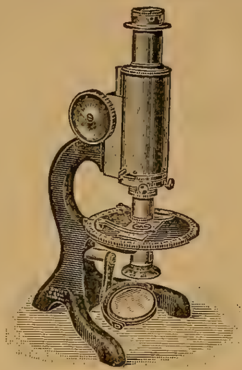
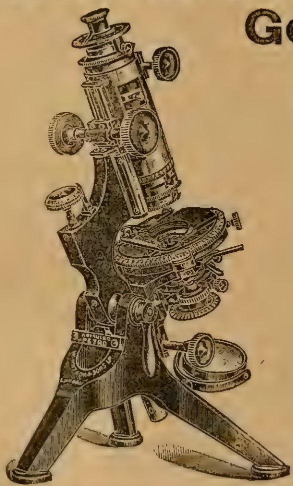




THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. X.—OCTOBER, 1917.

ORIGINAL ARTICLES.

I.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

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

VI. The Buccal Armature of *Conulus albogalerus*, Leske.

(PLATE XXVIII.)

1. Introduction.

Since 1824, when Charles Stokes transmitted to the Geological Society a drawing of the "buccal plates" of *Conulus*, the question of the existence and characters of the lantern in that genus has been intermittently, but inconclusively, debated. The course of this discussion may be briefly outlined here.

Desmoulins, in 1835, was of the opinion that the structures figured by Stokes were either jaws or teeth, but was uncertain as to which parts of the lantern-apparatus they might represent. Desor, in 1842, seems to have regarded these buccal plates as being the distal ends of the pyramids, being unaware that they were superficial structures with no inward prolongation. Forbes, in 1850, gave a figure of the "jaws and teeth", and in spite of the peculiar and improbable nature of these structures as depicted in his figure, echinologists of such experience as d'Orbigny and Wright accepted the drawings as representing genuine traces of the lantern. All the writers above mentioned were convinced that *Conulus* was a gnathostomatous form, basing their belief chiefly on a very reasonable analogy with other Echinoids in which the peristome is centrally placed. It is surprising that there is no record of any serious attempt at excavation of the interior of a specimen during the first fifty years of uncertainty. There is little difficulty in making preparations of the inner surface of the test of an Echinoid from the Upper Chalk, but the genius of a comparative anatomist was needed to demonstrate that fossils have insides no less than Recent forms.

Lovén and Duncan more or less simultaneously applied their energies to the elucidation of the detailed internal anatomy of fossil Echinoids, and, curiously enough, came to diametrically opposite conclusions as to the perignathic structures of *Conulus*. Lovén figured the perignathic girdle, and, while admitting the non-discovery of jaws, expressed his conviction that such organs were present. Duncan denied that there was a perignathic girdle in *Conulus*, at least of a functional kind, and definitely stated that jaws could not have existed in the genus. He ridiculed (with some justice) the figure of the teeth given by Forbes, ascribing them to grooves made in the infilling chalk of the specimen by the use of a graving tool. As a result of his denial of the existence of jaw-structures, he detached *Conulus* from its hitherto unassailed position among the Holectypoida (Echinoconidæ) and relegated it to the group containing *Pyrina* and *Echinonëus*.

That Duncan was wrong in denying the presence of a perignathic girdle in *Conulus* is patent to all who care to develop the interior of the adoral surface of any species of the genus; it is difficult to understand how so reliable an observer could have overlooked such an obvious structure, and have succeeded in blinding the perception of another worker of the standing of W. P. Sladen. Thus his chief argument against the occurrence of jaws in the genus is based upon inaccurate observation, and, indeed, recoils. Since there *is* a perignathic girdle, and the main purpose of such a development is for the attachment of the muscles that work the jaws, the presence of the latter structures must logically be inferred until disproved—a difficult or impossible proposition. The two sole bases for such a negative argument are, firstly, the non-discovery of the ossicles in question, and secondly, the obliquely elliptical outline of the peristome.

The transfer of *Conulus* to the Echinonëidæ by Duncan may or may not be justified, but an entirely different complexion was put upon such a change by the discovery by A. Agassiz in 1909, of a fully developed lantern in a post-larval *Echinonëus*. Although this vestigial lantern is resorbed before the mouth becomes functional, its complete development at such a relatively late stage in ontogeny is a clear indication that the recent Echinonëidæ have descended from ancestors which were gnathostomatous at no very remote period. The post-larval lantern of *Echinonëus* is associated with a simple, but defined, perignathic girdle. This girdle is completely resorbed at the same stage of ontogeny as the lantern. On the inevitable hypothesis that *Echinonëus* and *Conulus* are nearly, if not directly, related, it would be expected that the latter genus should show a longer persistence of the jaw-apparatus, but that, as its ontogeny progressed, the structures should steadily degenerate. The last anticipation, so far from being justified by the known facts, is directly negatived by them. The largest specimen of *Conulus albogalerus* in which I have studied the perignathic girdle shows that structure developed into far greater complexity and perfection of detail than it presents in smaller examples. Hence it is reasonable to argue that, since the loss of the lantern in *Echinonëus* coincides in time with the complete destruction of the perignathic girdle, the retention and specialization of the girdle in gerontic specimens of *Conulus* indicates that the lantern was persistent throughout life.

In 1911 I was able to describe and figure actual teeth, with characters and proportions little different from those of *Discoides*, in a specimen of *C. subrotundus*. The specimen is fully adult, but it is strangely anomalous to find such relatively small elements as the teeth when there is no trace of the usually far more massive pyramids. However, where there are teeth there must surely be jaws of some kind, so that it must be allowed that the species of *Conulus* were gnathostomatous at least as late as the period of the Middle Chalk.

The case is very different as regards *C. albogalerus*, the Upper Chalk species. The interior structures are readily accessible owing to the commonly soft nature of the matrix, but hitherto no indication has been found of any buccal armature save the perignathic girdle and the "buccal plates". In the paper referred to above I accepted the suggestion that the buccal plates might be curiously modified relics of the pyramids, and that the species was edentulous. One of the main purposes of this paper is to express an absolute and complete recantation of this suggestion. The arguments in the next section will, I think, suffice to account for, if not to explain, the peculiar nature of the buccal plates, and the latter description of the presumed fragments of true pyramids recently discovered will afford insight into the reason for their habitual non-preservation in a recognizable condition.

2. The Buccal Plates.

One of the most striking features of the Echinoid fauna of the Upper Cretaceous is the massiveness of the test-fabric. Such a genus as *Stereocidaris* illustrates this point very clearly; but it is most obvious in the Irregular Echinoids. A comparison between *Echinocorys* and the nearly allied recent genus *Urechinus* shows an extraordinary contrast in the thickness of the coronal plates. The "Heart-Urchins" of the present fauna are, for the most part, constructed of exceedingly delicate fabric, the test often being as thin as tissue-paper. But *Micraster* and *Hemiaster*, the Cretaceous representatives of the "Heart-Urchins", have tests of almost unwieldy thickness.

As a general rule, the Echinoids of the present day may be divided into two sections; those whose habitat is exposed, and those which live buried in sand or ooze. The former group comprises most of the Regular Echinoids, and may be illustrated, in an extreme case, by such a form as *Heterocentrotus*, in which the coronal plates may be as much as a quarter of an inch in thickness. Another type of "exposed" Echinoid is the "Sand-dollar", in which, even when the test is not very thick (as it is in *Clypeaster*), the whole fabric is supported by pillars and buttresses within. The latter group may be represented by *Echinocardium*, where the test is exceedingly thin and fragile. The difference in test-thickness is obviously, from one point of view, a mechanical adaptation to the requirements of the habitat. The strong test that will successfully resist the pounding of the waves can be almost dispensed with in the shelter of a burrow.

There is, however, small ground for believing that the surroundings of such a genus as *Micraster* were in any sense tempestuous; the reverse is more probable. So that the great thickness of the test in the Chalk Echinoids must be due to some other cause. Indeed, it would seem that they underwent excessive calcification quite independent of their mechanical needs; and this thickening was therefore likely to affect other stereom-structures besides the actual corona. The buccal-membrane plates of *Echinocorys*, as Lambert and I have described them, are far more robust than those of similarly sized Spatangoids of the present day, although far inferior in thickness to the coronal plates. The periproctal plates of *Discoides* are equally strong.[1]

In a specimen of *Conulus albogalerus*, the interior of which is almost filled with flint, there are numerous thick, granular plates in the mealy chalk within the periproct. They are like the buccal plates in every feature except that of shape, and I have not the slightest hesitation in identifying them as the plates of the periproct-membrane. Since the periproctal plates are so enormously thickened in this species, it is only to be expected that the peristomial ones should be in a similar condition. There is, therefore, good reason for believing that the buccal plates of *Conulus* are merely the plates of the buccal membrane, and that their strange proportions are but an advanced expression of the Upper Cretaceous "mode".

[*Note inserted in proof, September* 14, 1917. — The preceding paragraphs were written in July of this year. The Editor has kindly drawn my attention to two recent papers in this Magazine which include references to the phenomenon of "super-calcification" in Cretaceous forms. One, by W. D. Lang, deals with Polyzoa, and the other, by C. T. Trechmann, is concerned with Mollusca. The Editor has also reminded me of the extraordinary superfluity of shell-substance developed in the Rudistacea in the same period. In some cases it is easy and probably correct to ascribe the secretion of apparently unnecessary mineral matter to phylogerontic over-specialization (e.g. *Parkinsonia dorsetensis* from the Bathonian, and *Clavella longæva* from the Bartonian). But in the case of the "Heart-Urchins" above mentioned, such an explanation seems impossible. *Hemiaster*, *Micraster*, and *Epiaster* represent the progressive pioneers of the Spatangina, not degenerate and superannuated relics; and a quality that affects a large proportion of a fauna, irrespective of the phylum or phylogenetic phase of the individuals, must surely have originated from some more comprehensive and fundamental cause. However, this is not the place for a discussion of the problem.]

If the foregoing interpretation of the buccal plates is correct, an important corollary follows. Lovén showed that the young *Echinocardium flavescens*, where the outline of the peristome is roughly circular, has ten elliptical plates on the buccal membrane, arranged in a complete cycle near the circumference of the aperture. In 1912 I indicated the close correspondence in most characters between the early ontogenetic stage of the buccal plating in *Echinocardium* and the "buccal plates" of *Conulus*; but hesitated to correlate the two sets

[1] The same remark applies to the periproctal plates described by F. J. North (Ann. Mag. Nat. Hist., December, 1915). His specimen is obviously a species of that Upper Chalk Caratomid genus variously called *Echinoconus* (Desor, *fid.* Lambert), *Pironaster* (Schlueter), or *Conulopsis* (Hawkins). Anyhow, the horizon from which it was collected, and all the particulars published about it, show clearly that it is not a *Discoides*.

of structures owing to the "massive character of the latter ossicles". If the foregoing argument is sound, this difficulty disappears. Hence it is with confidence, bordering on conviction, that I now express the opinion that the "buccal plates" of *Conulus albogalerus* represent the Cretaceous phase of the plating of the buccal membrane which is recapitulated during ontogeny in the earliest post-larval stage of *Echinocardium flavescens*. This does not necessarily imply a direct phyletic sequence between *Conulus* and the "Heart-Urchins"; it is rather a fresh illustration of morphic parallelism independent of actual phylogeny. But it entirely destroys the arguments put forward by me in 1911 (Geol. Mag., p. 73), and cancels the hypothetical diagram there given (Pl. III, Fig. 8).

3. The Perignathic Girdle. (Pl. XXVIII, Figs. 1–3.)

(a) *The Angle of Inclination.* (Pl. XXVIII, Figs. 2, 3.)

The elements of the girdle in the Holectypoida, when viewed from within, always show a slope outwards from the peristome, thus contrasting with those of the Regular Echinoids, which are comparatively vertical in direction. In *Conulus albogalerus*, as in *Discoides* (see Part V of this series), the greater part of the girdle reclines against, or is bevelled off from, the proximally thickened interambulacra. There are thus two roughly circular rings whose diameters may be measured: the actual peristome margin and the upper limits of the girdle. In a young specimen of *C. albogalerus* (Fig. 3), where the diameter of the adoral surface is about 25 mm., the former diameter is *c.* 4 mm. and the latter *c.* 6·5 mm. In a gerontic specimen (Fig. 2), with an adoral diameter of about 48 mm., the corresponding measurements are 5 mm. and 9 mm. respectively. Reducing these measurements to a proportionate scale, we arrive at the following result:—

	Diam. of peristome.	Diam. of top of girdle.
Young specimen . .	1	1·62
Old specimen . . .	1	1·80

Specimens of intermediate sizes give proportionate results between these two extremes. Thus the obliquity of the girdle appears to increase with age. However, the vastly greater thickness of the interambulacra in the old specimen automatically increases the "splay" of the bevelling, and in reality the obliquity of the girdle is considerably less in the gerontic than in the small specimen. The approximate angles between the girdle and the plane of the adoral surface in the two examples are as follows:—

Young specimen	12°
Old specimen	25°

The actual inclination of the girdle in the fully grown example is thus more than twice as steep as that in the young one. This result has been checked by the measurement of the angles in twenty-eight specimens of intermediate size. It is somewhat surprising to find a decrease in obliquity during the growth of

Conulus—the reverse would have been anticipated. From *Plesiechinus* onwards the record of the perignathic girdle is one of ever-increasing obliquity, and in the Clypeastroids the angle between the plane of the adoral surface and a line joining the peristome-margin to the top of the girdle is very acute. The reversal of the trend of evolution in *Conulus* would thus seem to indicate that there is no direct phyletic course from the Holectypoida to the Clypeastroida by that route ; a conclusion that is supported by most other morphological indications. But it is a reversion towards the "Regular" character, and as such might be held to imply that the jaws of *Conulus* "improved" in quality during ontogeny. On the other hand, it seems equally logical to suggest that the continued thickening of the proximal parts of the interambulacra prevailed over the failing girdle, so that its increased slope is an expression of its waning functional importance. On general grounds, I incline to accept the latter alternative as the probable explanation of this anomalous feature.

(b) *The Structure of the Girdle.* (Pl. XXVIII, Figs. 1 and 2.)

The general characters of the girdle of *C. albogalerus* are well known, and little in the way of description needs to be added to the account given by Lovén in *Echinologica.* The chief problem is concerned with the interpretation of the observed structures. For this purpose I have chosen the very large specimen to which reference has been made in the preceding section, since this shows all the details of the girdle with an exaggerated clearness. The peristome is elliptical, with its long axis in the direction 3, I.

The general plan of the girdle strikingly resembles that of a Tudor rose. The five "petals" rise sharply from the peristome-margin in concave and embayed escarpments. Outside them the interambulacra rise to a slightly greater height, and then gently slope down towards the ambitus. The "petals" are separated from one another by the deep and narrow sulci of the ambulacra. The lateral margins of a "petal" consist of slender, projecting processes, based upon the bordering ambulacra, and visibly sutured to the main structure. Each process culminates distally in an almost spherical and glossy knob, which projects upwards and inwards beyond the general level of its surroundings. The "petal" itself may be considered to consist of three parts. There is a central prominence on the peristome border, rising sharply and culminating in a bevelled crest. Above this the chief part of the "petal" rises in a deeply concave slope, bisected by a median carina, which, though prominent, is also concave in the upward direction. At the top of the structure, overhanging the bays and carina of the main surface, is an almost flat area which slopes very gently towards the peristome, and has an imperfectly defined rim distally. (This platform is practically non-existent in smaller examples.) Beyond the platform the inter-ambulacrum rises a little above the sulcate suture which bounds the girdle, and then falls away gently towards the ambitus. The only sutures that I have been able to detect with certainty are (1) those between the bordering processes and the "petal", (2) a crescentic boundary suture between the platform and the normal interambulacrum, and (3) an interradial suture bisecting the carina. In addition, there appears to be a suture between the prominence and the carina, but it is by no means clear, although the junction between these two parts of the structure is very sharply defined.

The only additional ingredient of the girdle is the narrow, but proximally striking, carina which occupies the line of the perradial suture. The bulbous proximal end of this carina extends inwards beyond the normal circumference of the peristome. It is presumably developed for the stiffening of the thin coronal plates of the ambulacrum, which would otherwise seriously weaken the cohesion of the adoral parts of the test; but it may possess a further function, to which reference will be made later. The carina covers and quite obliterates the perradial suture.

(c) *The Homology and Function of the Structures.*

A comparison of the elements of the girdle of *Conulus* with those of *Discoides* (see Part V of this series) reveals an essential similarity. The processes are quite obvious. The central interradial prominence on the peristome-border is clearly the "true ridge", while the remainder of the interradial structure represents the "false ridge". Assuming the existence of a lantern, the retractors will have been attached to the upper parts of the processes, and the protractors to the true ridges. The false ridges, by analogy with those of *Discoides*, will have served as a rest or slide for the inclined pyramids. The only serious difference in the girdle-structure between *Discoides* and *Conulus* is found in the false ridges. In *Discoides* each false ridge is practically an inclined plane, with a very faint median concavity. In *Conulus* it has a concave surface, with a median carina, deeply excavate sides, and an overhanging summit. I believe that these three features are all to be associated with the curious nature of the buccal plates. The pyramids of the lantern would rest upon the true ridges and the gently inclined summits of the false ridges, and so would leave considerable spaces between themselves and the deep hollows, and even the carinæ, of the slopes of the false ridges. When the mouth was opened the massive buccal plates would inevitably need to be shifted, and it is hard to imagine more likely or suitable places for them than the deep slots in the false ridges. The median carina and the projecting edges of the processes would ensure their sliding in the right direction (so as to avoid confusion with the protractor muscles), and the proximal bulb of the perradial carina might have served to start them on their proper course when retracted. Thus the view put forward by me in 1911 as to the movement and disposal of the buccal plates still holds good, although I now disbelieve in the homology between those plates and the lantern-pyramids.

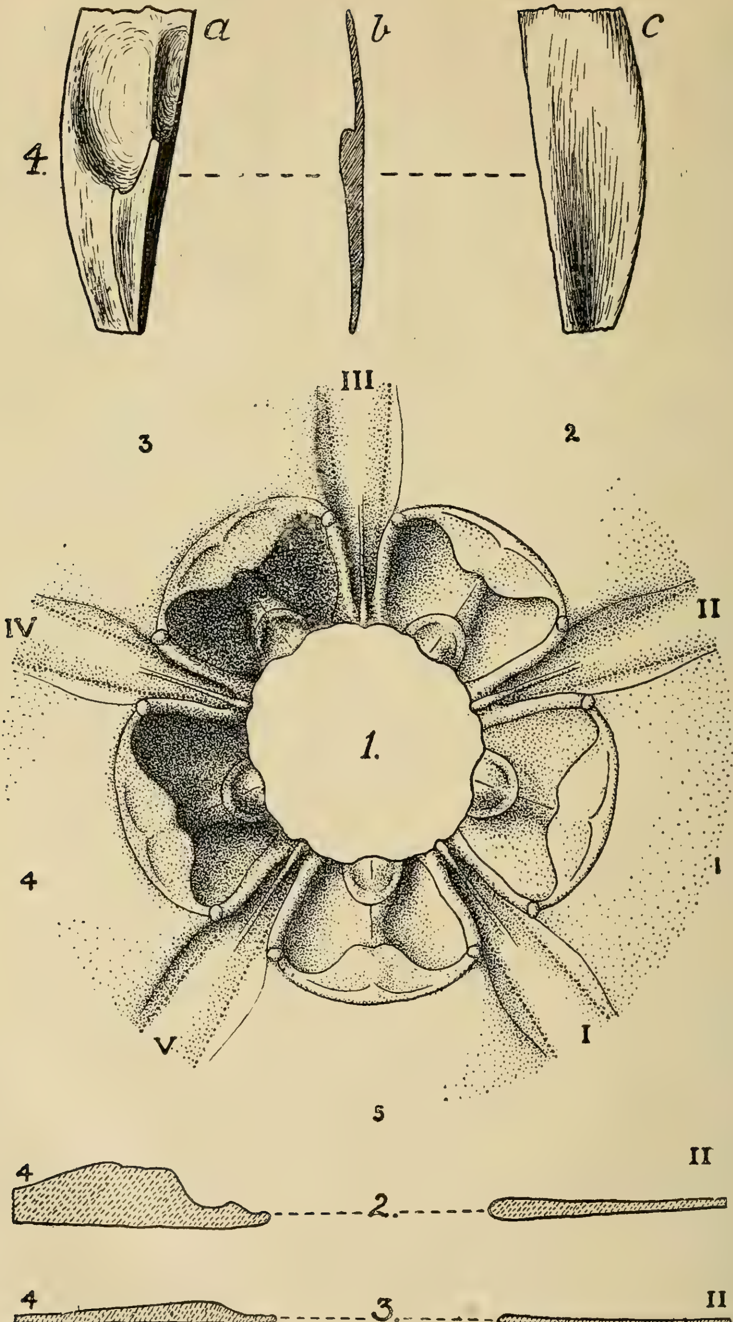
If the lantern was of a "flaring" nature (as would be probable in view of its character in *Discoides* and the Clypeastroida), it must perforce have come very near to, if not into contact with, the upper part of the perignathic girdle. Whether it articulated with the glossy knobs at the summits of the processes is a matter of doubt, but such an arrangement would be in keeping with the Clypeastroid character. But it might well have reclined upon the "platform" of the false ridge, bridging across the concavity between that and the peristome margin, and leaving space for the buccal plates to be retracted behind it. Such speculations are, however, of little value until more is known of the structure of the pyramids.

4. The Lantern.

When the chalk infilling of a test of *Conulus albogalerus* is brushed down, it proves to be surprisingly full of small, usually fragmentary, pieces of calcite. These are naturally often portions of Foraminifera, Polyzoa, or Pelecypod prisms that have drifted in with the ooze. But the fact remains that these fragments seem more thickly scattered through the internal than the external matrices. I have destroyed several hundreds of specimens of *C. albogalerus* in my hitherto vain endeavours to find the jaws; and in one example only, from the top of the *M. coranguinum* zone near Kingsclere, have any reasonably satisfactory portions been observed. Their nature explains the peristent way in which they elude recognition. They are small, and so delicate in texture that they are translucent, and the friction due to even a soft tooth-brush readily shatters them, if applied at random. In the specimen here noted the chalk within the test was almost powdery in consistency, and was removed with a camel's-hair brush. Two or free fragments, which seem to represent pyramids, were extracted, but they are so broken and difficult to orientate that I prefer to postpone full description of them in the hope of procuring better specimens.

I have selected one of the fragments (3 mm. long and about 1 mm. broad) as indicative of the general characters of these interesting ossicles. It is shown on Pl. XXVIII, Figs. 4, *a*, *b*, *c*, from three points of view, *a*, *b*, and *c*. How far its outlines are natural or are the product of fracture is difficult to determine. The fragment is roughly triangular, and excessively thin. The top and bottom are both broken. One side is gently crescentic in shape, and the other almost straight. I believe that the curved side is a natural margin, but whether the straight edge is natural or the result of cleavage I cannot determine. One surface (*a*) shows a carina passing longitudinally near to the straight margin at the broader end of the surface, and separating two ovoid excavations. Towards the narrower end the ossicle is thicker, the carina less prominent, and one side of the surface is gently bevelled. A comparison of this figure with that of the alveolar view of a maxilla of *Discoides* (Geol. Mag., 1909, Pl. VI, Fig. 5) shows an almost startling resemblance. If the straight edge of the *Conulus*-ossicle is taken to be a cleavage line, cutting the maxilla vertically and removing the inward extension of the inter-pyramidal joint-face, the likeness between the figures is complete in all save proportions. The two figures are supposed to be similarly orientated.

Fig. *b* is a view of the (?) cleavage margin of the ossicle. It shows the extreme tenuity of the structure at the broad, excavate end, and its superior massiveness at the narrow end.



H. L. H. del.

PERIGNATHIC GIRDLE OF *CONULUS ALBOGALERUS*, LESKE.

Fig. *c* shows the opposite side of the ossicle to that drawn in Fig. *a*. It is not quite parallel to that side, but makes a very acute angle with it. Save for a slight median sulcus, increasing in depth towards the narrow end, it is plain. It is very suggestive of the external surface of the maxilla of *Discoides* (loc. cit., Fig. 2), but only if the straight edge of the ossicle is regarded as the symphysial margin instead of a cleavage line.

It is difficult to imagine that this fragment can be other than a part of a maxilla, and still more difficult to doubt that it belonged to the specimen in which it was found. Other fragments include one which suggests the existence of alar expansions like those of the Clypeastroida (with a similarly reticulate character), and another that is presumably part of a stirodont tooth. For the reason stated above I prefer to leave all detailed discussion of these structures to the future. The specimen figured is sufficient to indicate the grounds for my belief that the lantern of *C. albogalerus* has been found at last.

5. Summary.

The perignathic girdle of *Conulus albogalerus* is shown to resemble closely that of *Discoides*, with modifications due to the greater degree of thickening of the interradial coronal plates and to the massive character of the buccal plates. These are considered to be the true plates of the buccal membrane, and to have been capable of retraction into the deep sockets of the false ridges of the girdle. The existence of a lantern is inferred as a result of arguments based upon the known characters of the girdle and upon analogy with related types. Certain imperfect ossicles found within the test of a small specimen are considered to represent portions of the lantern; and one, here figured, seems clearly to be a fragmentary maxilla similar in all essentials to that of *Discoides*, but differing in shape and proportions. Further discussion of the presumed lantern is deferred until better material is acquired.

The next paper in this series will deal with the perignathic structures of the Holectypoida as a whole, with a discussion of the internal characters of the peristomes of some early Spatangoida.

EXPLANATION OF PLATE XXVIII.

Fig.

1. Perignathic girdle of a gerontic specimen of *C. albogalerus*. × *c*. 6. All sutures except those at the sides of the processes are omitted. There is a suture down the middle of each false ridge, but the median lines on the true ridges represent the crests of carinæ, not sutures. The outlines of the various parts are slightly emphasized, but otherwise the figure is not diagrammatic.
2. Section along the axis 4, II, of the same specimen. × *c*. 6.
3. Section along the same axis of a smaller specimen. × *c*. 9. The "platform" of the false ridge is indistinguishable.

4, *a*, *b*, *c*. Fragment of presumed maxilla from the interior of a small specimen of *C. albogalerus*. × *c*. 14. *a*. ? Alveolar view, showing ? distal hollows, ? symphysial surface (on the left), and ? dental slide (on the right). *b*. Side view along the straight edge of the fragment. *c*. ? Outer view, showing the shallow sulcus deepening towards the narrow (? proximal) end.

II.—Observations on the genus *Polymorphites*.

By A. E. Trueman, M.Sc., University College, Nottingham.

In 1843 Simpson published a description of a Yorkshire Ammonite previously named *Ammonites trivialis* in Bean's manuscript.[1] A few years later Quenstedt described a number of small continental Ammonites of similar character as *A. polymorphus*, which he further divided into the varieties *lineatus*, *costatus*, *interruptus*, *mixtus*, and *quadratus*. The specimens he then figured must be taken as his types[2]; in a later work[3] he showed many more examples which he referred to the same species; all these have small, evolute shells, but few other common characters, so that the name *polymorphus* was fully justified. For example, the illustrations given as *Ammonites polymorphus mixtus* include forms with round or square whorls, with nearly straight or with curved ribs, which may pass across the venter with or without a forward bend, or may be suppressed entirely on the venter. The specimens figured probably include young examples of several different genera.

Sutner and Haug[4] systematized our knowledge of these fossils and established the genus *Polymorphites*, while Simpson's specimens have recently been figured and described by Buckman[5] as *P. trivialis*, Bean–Simps.; *P. mixtus*, Qu.; *P. jupiter*, d'Orb. The following notes are mainly concerned with these three species. Most of the specimens used in this work were pyritized casts obtained from the Lower Lias clays on the tunnel heaps at Old Dalby in North Leicestershire; accordingly their precise horizons cannot be given. With them there were also found *P. caprarius*, Qu., *P. quadratus*, Qu., and other fossils of the *valdani*-zone. For permission to make use of the abundant material in the collections at University College, Nottingham, and for much help in the work, I desire to express my thanks to Professor H. H. Swinnerton. Mr. S. S. Buckman has also kindly given valuable suggestions.

Comparison of the Species.

Polymorphites trivialis is a costate form; occasionally a strongly ribbed example may show a row of elongate tubercles on the external margin. The venter may be somewhat angular, thus resembling *P. caprarius*, but frequently it is more or less rounded in the adult, when the form may approach *P. quadratus*.

P. mixtus is less strongly ornamented; in the development of this species the shell is at first smooth, then striate, and in the adult subcostate to costate. In this respect it is intermediate between *P. trivialis* and *P. jupiter*, which is an evolute simple form, smooth until a diameter of about 4 mm. is attained, when slightly curved striæ are developed. The developments of these forms are compared

[1] M. Simpson, *Monog. Lias Ammonites*, London, 1843.
[2] F. A. Quenstedt, *Die Cephalopoden*, 1849, pp. 86–7, tab. 4.
[2] F. A. Quenstedt, *Die Ammon. de Swäb. Jura*, 1885.
[4] E. Haug, "Ueber die Polymorphidæ": Neues Jahrb. f. Min., 1887.
[5] S. S. Buckman, *Yorkshire Type Ammonites*, vol. i, No. 53, 1912.

in the table. The numbers there given refer to the ornament cycle of Buckman.[1]

Diam. (mm.)	*P. trivialis.*		*P. mixtus.*		*P. jupiter.*	
25	Tuberculate	5*	Costate	4	Striate	2
20	Costate	4	Costate	4	Striate	2
15	Subcostate	3	Subcostate	3	Striate	2
10	Subcostate	3	Subcostate	3	Striate	2
5	Striate	2	Striate	2	Smooth	1
2	Smooth	1	Smooth	1	Smooth	1
1	Smooth	1	Smooth	1	Smooth	1

Occurring with these species at Old Dalby is a form which outwardly resembles *P. jupiter*, but which has costate inner whorls and is probably a catagenetic offshoot of *P. trivialis*. A similar example was figured by Buckman,[2] who considered it to be *P. jupiter* showing temporary catagenesis, but who now suggests[3] that the persistence of the striate ornamentation indicates that it is a different species. For convenience this degenerate form is here referred to as *P.* cf. *jupiter*.

Fig. 11.

Fig. 11.—*P. mixtus.* *s*, last suture; *m*, mouth margin.

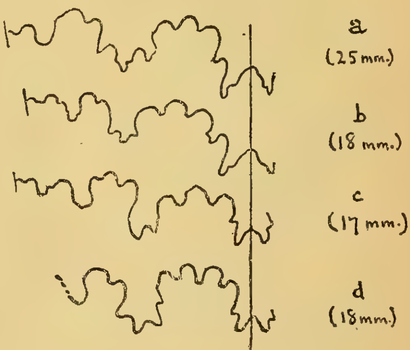
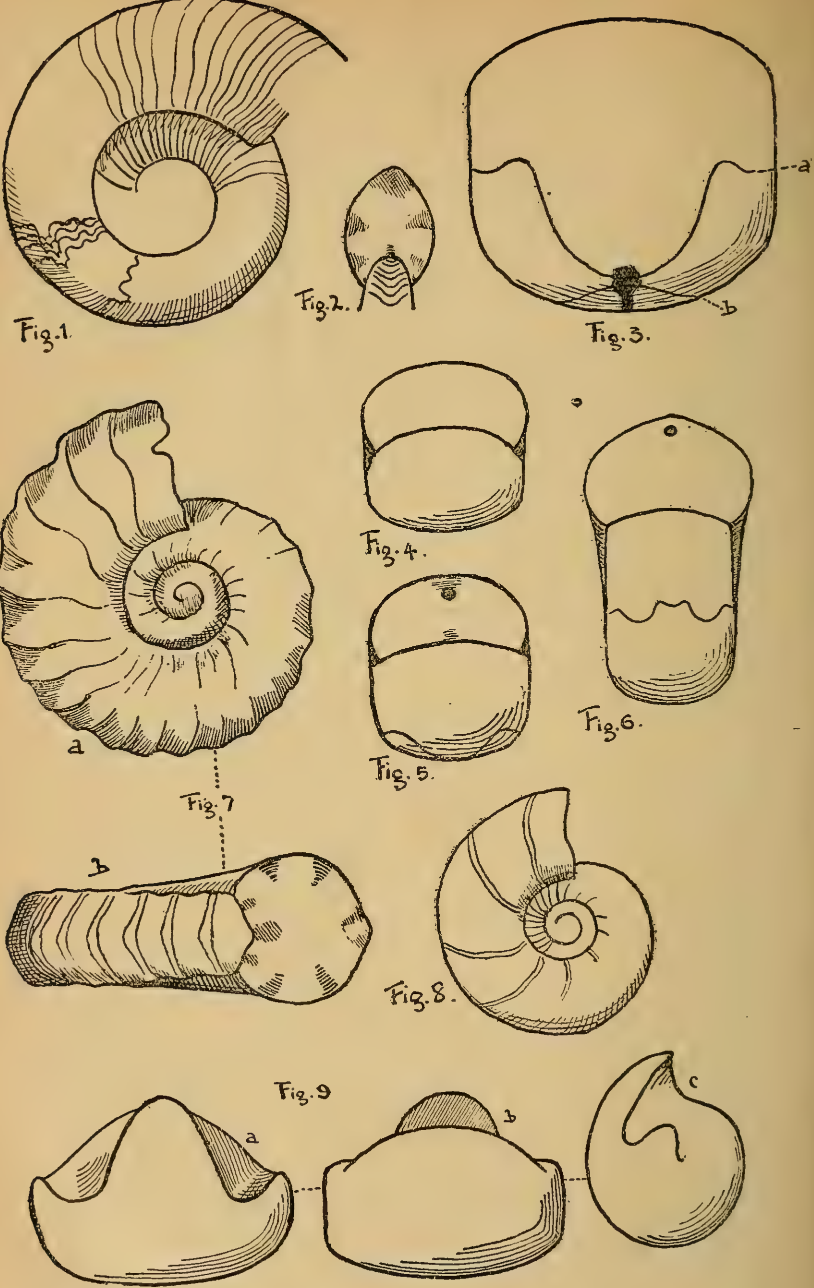


Fig. 12.—Adult sutures of *Polymorphites.* *a*, *P. trivialis*; *b–d*, *P. mixtus.*

The adult sutures of some specimens of *P. trivialis* and *P.* cf. *jupiter* have saddle terminations more rounded than others (Fig. 12*a*), and the external saddle may have either three or four terminal folioles. In nearly all cases the last three or more sutures are closely crowded (Figs. 1, 11), a feature which is also shown in some of Quenstedt's figures.

In examples of *Polymorphites* the mouth margin is not usually preserved, but a specimen of *P. mixtus* shows a mouth border preceded by a constriction (Fig. 11); in this case the length of the body-chamber is half a whorl.

[1] S. S. Buckman, *Yorkshire Type Ammonites*, vol. i, p. xiii.
[2] Ibid., No. 53*c*.
[3] *In litt.*, August 3, 1917.



The Development of *Polymorphites jupiter*. Fig. 1, adult (30 mm.); Fig. 2, arched venter (at diam. 8 mm.); Fig. 3, early chambers, × 72; Figs. 4–6, successive stages (diam. ·7, ·75, 1·2 mm.); Fig. 7, costate stage (2·8 mm.); Fig. 8 (8 mm.); Fig. 9, protoconch, × 63.

J. F. Blake[1] pointed out that in the Yorkshire examples of *A. trivialis* the inner whorls are not usually preserved. The earlier chambers, however, are present in occasional specimens from Old Dalby, and the development may be studied without much difficulty in *P.* cf. *jupiter*.

THE DEVELOPMENT OF *POLYMORPHITES* CF. *JUPITER*. (Figs. 1–9.)

The protoconch, which is not often preserved, has axes of ·56 mm. and ·4 mm. respectively, and shows the usual angusti-sellate characters. The whorl section is depressed in the early stages (see Figs. 4 and 5), and does not become as high as wide until a diameter of 4 mm. is reached. Before this time (at about 1 mm. diameter) a somewhat angular (convexi-fastigate) venter is developed (Fig. 6), and at a diameter of 2 mm. low curved folds appear. During the next whorl the venter becomes more angular and the folds more prominent, especially on the venter, where they bend sharply forwards (Figs. 7*a*, *b*), causing a superficial resemblance to the crenulate keel of the Amaltheidæ.

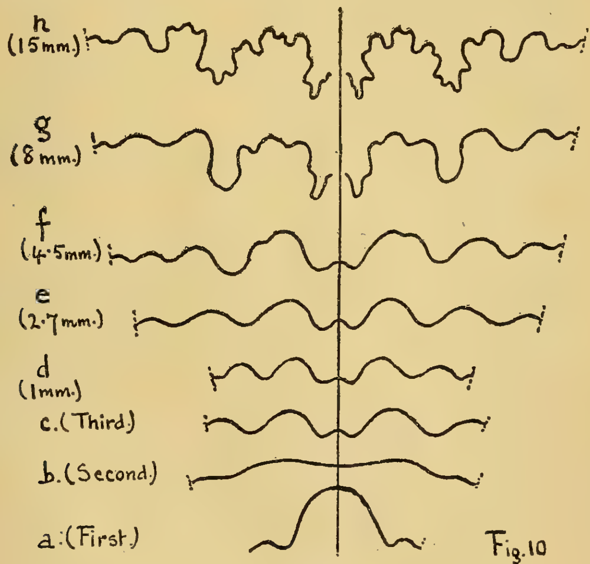


FIG. 10.—Sutural development, *P.* cf. *jupiter*.

This costate stage persists until the shell attains a diameter of 6–9 mm., when it is succeeded by a subcostate stage, low folds alternating with striæ of similar form (Fig. 8), which presently are developed to the exclusion of the folds (Fig. 1); by this time whorl height appreciably exceeds whorl thickness and the venter is rounded or slightly angular. In later life the striæ become less prominent.

The account of the development just given applies to most of our

[1] In Tate & Blake, *The Yorkshire Lias*, 1876, p. 292.

specimens. In a number of cases slight modifications occur; for example, in some forms striæ are developed before the low folds (as in Fig. 8). In one example, the outer whorl of which was similar to *P. jupiter*, the inner whorls to a diameter of 9 mm. had the characters of *P. caprarius*. This suggests that the forms known here as *P.* cf. *jupiter* may be polyphyletic, being catagenetic descendants of several more highly ornamented forms.

The sutural development (shown in Figs. 10*a–h*) does not vary greatly in the different species considered. The first suture shows the narrow external or azygous saddle flanked by small lateral saddles (Fig. 10*a*). In the second suture this external saddle is divided by a low ventral lobe, a primitive stage which is omitted in the development of more highly specialized ammonites. In the third suture the ventral lobe is much deeper and is already divided by a small median saddle; the external and lateral saddles are by this time higher, though still not so high as wide (Fig. 9*c*). Not until the diameter of 1 mm. is attained is there any marked advance on this stage, a small auxiliary saddle being then developed (Fig. 10*d*). At the diameter of 4·5 mm. another auxiliary is present and the first indication of frilling has appeared on the dorsal side of the external saddle. By the fifth whorl (at a diameter of 8 mm.) the external saddles show the well-marked divisions which are characteristic of the adult. It will be noticed that the lateral elements appear to have swung forwards, so that the anterior borders of the external and lateral saddles are approximately level, although the external saddle is much larger than the first lateral.

Connexions with other Genera.

Several views have been expressed concerning the systematic position of the species considered. For instance, Blake referred *A. trivialis* to *Amaltheus*, the knotted keel of the young possibly being his main reason, while Wright referred them to the comprehensive genus *Ægoceras*.

Important progress in studying the relationships of *Polymorphites* and allied forms was made by Haug, who showed that the "keeled" young was quite unlike a young *Ægoceras*, and suggested that *Polymorphites* was descended from *Agassiceras miserabile*. The simple but wrinkled suture shown by this ammonite, however, can scarcely be compared with the early suture of *Polymorphites*. Haug further suggested that the evidence of genetic connexion is confirmed by the occurrence of asymmetric sutures in each of these genera, but this character is rarely sufficiently constant to be used as a test of affinity, and, moreover, asymmetry is not common in British specimens of *Polymorphites*.

More recently Buckman has suggested that *Cymbites* is the radical of *Polymorphites*,[1] and the facts of development support this view. Thus, the shell form of *P. jupiter* at a diameter of 1 mm. closely resembles that of *Cymbites globosus* at 10 mm. diameter. A comparison of the sutural developments of *P.* cf. *jupiter* and *C. globosus* (see

[1] S. S. Buckman, "On the genus *Cymbites*": Geol. Mag., 1894, p. 361.

Fig. 13[1]) affords additional evidence. In each of these two forms the high median saddle of the first suture gives place in the second suture to a broad, shallow median lobe, which is in each case divided by a median saddle in the third suture. The development of folioles and their arrangement in the adult suture point to a close relationship between *Polymorphites* and *Cymbites*. The length of the body-chamber in the two genera is about half a whorl, although *Cymbites* appears to have a different form of mouth from that of *Polymorphites*.[2]

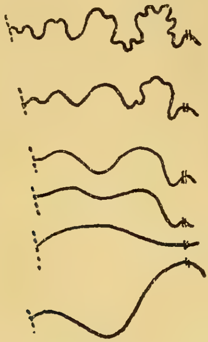


Fig. 13.—Sutural development of *Cymbites globosus* (after Branco).

Cymbites lævigatus is in some respects intermediate between *C. globosus* and *Polymorphites* in being more evolute, feebly costate, and often having a slightly angular venter, which is not developed, however, until a diameter of 12 mm. is reached.[3] It is thus extremely probable that *Polymorphites* is derived from a form resembling *Cymbites globosus*, possibly through *C. lævigatus*. Such a position near the radical stock would account for the primitive characters noted, and for the amount of variation in different representatives of the genus.

III.—The Pahang Volcanic Series.

By E. S. Willbourn, B.A., Assistant Geologist, Federated Malay States.

(WITH PLATE XXIX AND A MAP, PLATE XXX.)

Introduction.

The name Pahang Volcanic Series was given by Mr. J. B. Scrivenor to those eruptive and intrusive rocks of the Malay Peninsula which are older than the Mesozoic granite, and the rocks were described by him in *The Geology and Mining Industries of Ulu Pahang*, 1911, ch. xi. As the name implies, the series is most strongly developed in Pahang, but it is also developed to a greater

[1] After W. Branco, *Beit. Entwick. foss. Ceph.*, Th. i, tab. xii, 1879.
[2] E. Dumortier, *Dépots Bassin Rhône*, pt. iii, pl. xviii, figs. 3, 4, 1869.
[3] A. Hyatt, "Genesis Arietidæ": Smithsonian Contributions, No. 673, pl. viii, fig. 10, 1889.

or less extent in Singapore *[1] Island,[2] Johore *, Negri Sembilan *, Selangor *, and Perak *, and possibly also in the more northern states, Kedah *, Kelantan *, and Trengganu *. The present account deals for the most part with the main development in Pahang, and most of the information was obtained on two trips, one to examine the railway-cuttings from Gemas * to Kuala Lipis, and the other to examine outcrops over a distance of about 100 miles in the rivers Jelai and Pahang, from Kuala Lipis to Mengkarak.

A large part of the first trip was fruitless, for the railway cuttings over a distance of 80 miles in Negri Sembilan * and part of Pahang were so much weathered that they conveyed practically no information. For instance, it was impossible to determine whether certain sandy strata intercalated with shales near Kerdau railway-station were weathered quartzites or volcanic-tuffs, and it is possible that the Gondwana outcrop extends further to the north than is represented on the map, whereas, on the other hand, it may be incorrect to leave the 20 miles of river and railway below Kuala Tekal barren of Pahang Volcanic Series rocks, and indeed, in the sketch-map attached to the above memoir, Mr. Scrivenor indicated their presence along this stretch. Between Kuala Krau and Kuala Lipis, and particularly along that part between Kuala Tekal and Kuala Lipis, there were some excellent exposures, but at the time when the trip down the Rivers Jelai and Pahang was taken the river was not low, and so many exposures which had previously been described by Mr. Scrivenor were not seen on this occasion.

Great use has been made of the information and specimens collected by Mr. Scrivenor from different rivers and from the Benta–Kuantan road, and the occurrences of Pahang Volcanic Series rocks represented on the Map (Plate XXX[3]) in all districts, excepting the railway and Rivers Jelai and Pahang, have been copied from his 1911 sketch-map.[4]

Associated Rocks.

The Pahang Volcanic Series is associated with the sedimentary rocks of the Raub, and also, to a less degree, with Gondwana rocks. The Raub Series is the more prominent in the Pahang Valley, and consists of limestones and calcareous shales, the colour of the limestones varying from white to black, according to the quantity of carbon they contain. The greater part of the Gondwana rocks is made up of quartzites, grits, and shales, the exposures of quartzite being usually weathered to sandstone except in fresh cuttings, though occasionally "core-boulders" of hard quartzite are found. In many parts of the Peninsula cherts are seen at the base of the Gondwana rocks, and in Negri Sembilan * several exposures east of the Main

[1] An asterisk marks the names of all those places in Malaya mentioned in the text which are outside the area shown on the accompanying Map, Plate XXX.

[2] Described by Mr. Scrivenor in the Geol. Mag., Dec. V, Vol. VI, pp. 17–22, January, 1909.

[3] The Map will appear in the second part of the paper in November.

[4] The photographs of rock-sections illustrating this paper (Plate XXIX) were taken by Mr. Scrivenor, to whom I now tender my best thanks.

Range show cherts interbedded with quartzites, that is, with Gondwana rocks. A chert band at Lubok Plang, associated with Raub rocks, indicates that there was a series of cherts older than that associated with Gondwana rocks, and the occurrence in Gondwana conglomerates of pebbles of chert which had been veined before being rounded as pebbles shows that there was a considerable unconformity after the Raub period and before the deposition of the Gondwanas.

The relations of the sedimentary rocks of the Peninsula to one another are expressed shortly in the following table. No Tertiary rocks have been seen in Pahang.

Series.	Nature of Rocks.	Remarks.
	Recent deposits.	Including coastal alluvium, etc.
	Unconformity.	
Tertiary.	Shales and sandstones, with coal seams, at Rantau Panjang*, Enggor*, and Perlis*. No outcrops known in Pahang.	Tertiary plant remains.
	Unconformity.	The main range granite was intruded, with folding and shearing of the sedimentary rocks.
Gondwana Rocks.	Shales and quartzites. Pahang Volcanic Series and cherts. The Myophorian sandstone.	With fossils of Rhætic period.
	Unconformity. Boulder-in-tuff deposits formed now ?	Volcanic activity was in full swing.
	The Pahang Volcanic Series. Cherts (in situ at Lubok Plang, Pahang River, and as pebbles in Gondwana quartzites all over the Peninsula). Shales and limestones (in L. Selangor* and east of Negri Sembilan*). Altered shales (talc schists and phyllites), west of Negri Sembilan*. This series may be younger than the limestones.	Some Raub shales in Pahang contain Permian fossils. Fossils from limestone in Pahang are Carboniferous.

Fossils are rarely met with, but a collection made by Mr. Scrivenor from a limestone hill near Kuala Lipis indicates a Carboniferous age for the Raub Series, and the fossiliferous Myophorian sandstone at the base of the Gondwana rocks corresponds to the Rhætic period. Some fossils in shales at Lubok Sukum indicate a Permian age for the beds there. Shales and sandstones, i.e. Gondwana rocks, are exposed near here, but at the time the trip was made down the Pahang River the fossiliferous shales were not exposed, and Mr. Scrivenor, who collected the fossils, was of the opinion that they occurred in Raub rocks. The field evidence of the relations of the Raub shales and limestones in Pahang suggests that they constitute an alternating series, and that some Raub shales are older, whilst others are younger, than the Raub limestones, but in other districts, for instance in Negri Sembilan*, there is a possibility that the upper part of the Raub Series consisted of calcareous shales which are now (in Negri Sembilan) altered to phyllites and talc schists.

Distribution of Pahang Volcanic Series throughout the Peninsula.

The Map (Plate XXX) indicates the known places of occurrence in the area of greatest development in the Peninsula, but it must be remembered that little is known of the country not actually penetrated by rivers, roads, or railway. All places mentioned in the text that are not marked on the Map occur outside this area.

It is clear that volcanic activity was stronger during the Raub period than during the deposition of the Gondwana rocks which followed. In the south of Negri Sembilan* and north of Johore* there is a considerable development of Pahang Volcanic Series tuffs, but few lavas or intrusive rocks have yet been noted there. In Singapore* certain core-boulders of quartz-porphyry and dolerite have been examined by Mr. Scrivenor,[1] but as the rocks do not occur in situ nothing can be said about their age. Similar core-boulders have been found on the Kuala Lumpur* to Bentong* road where it crosses the Main Range, and their age too is rather a matter of doubt, but there is little doubt as to the age of an igneous rock like a lava which is found near here interstratified with chert being that of the Pahang Volcanic Series. There are numerous exposures of a porphyritic rock which forms the greater part of the hill-cap, and is seen in road-cuttings both on the Selangor* and Pahang side of the Main Range. It contains abundant colourless rhombic and monoclinic pyroxene, biotite, quartz and felspar (oligoclase and labradorite) set in a fairly fine-grained mosaic of felspar (some of it labradorite) and quartz. This rock, which may be termed granite-porphyry, and the quartz-porphyry which occurs as core-boulders, are both fresh, and contain no calcite or epidote, but they show signs of considerable shearing.

The quartz-porphyry is seen in situ at Jeram Gading*, a tributary of the River Klang*, near its source (outside the area shown on the Map), and forms a steep gorge about four miles upstream from the point where the tributary flows into the main river. In this gorge

[1] Geol. Mag., Dec. V, Vol. VI, No. 535, January, 1909.

the quartz-porphyry is seen to be traversed by numerous good joint planes which are much more strongly developed than, for instance, is the case in granite, and their distribution at rather irregular intervals causes the rock to separate into angular blocks of very different sizes. Here is seen what is sometimes noticed in granite, namely, that the transition from unweathered hard rock to soil is very abrupt and that there is no partially decomposed rock. At first sight it would appear that the freshness of the rock as seen on the Kuala Lumpur–Bentong* road is against its being older than the Mesozoic granite, but there are signs that it has been brecciated and subjected to strong shearing, and any secondary minerals that were formed before those movements may have been reconstituted. Some specimens from Jeram Gading* contain epidote in abundance, and the presence of this mineral, which is characteristic of the igneous rocks older than the granite, is an indication that the quartz-porphyry belongs to the Pahang Volcanic Series, and the numerous boulders of volcanic tuff and breccia, also containing epidote, which can be seen in the stream show that rocks of the series occur in the neighbourhood. In addition, pebbles and boulders of hornblende-augite-schist were seen in the Rivers Seli* and Klang*, and one specimen when examined under the microscope revealed that the schist was originally a porphyritic igneous rock. Similar schists and gneisses in situ bordering the alluvial plain of Kuala Lumpur* are penetrated and altered by the Main Range granite, and the field evidence goes to show that the schistose structure was induced by the earth-movement which took place when the granite was intruded, so it is probable that they were originally rocks of the Pahang Volcanic Series. A single boulder of the quartz-porphyry was found lying on weathered granite at the eighth mile from Kuala Lumpur* on the Rawang road*, and one boulder of the pyroxene-granite-porphyry was found at the foot of Bukit Lanjan*, near Kepong, in Lower Selangor, so it appears that there was a widespread occurrence of the Pahang Volcanic Series in Selangor, but that a great part of it has been denuded since the intrusion of the Main Range granite.

The different types of rocks belonging to the Pahang Volcanic Series are indicated in the following table :—

SERIES.	ACID.	INTERMEDIATE.	BASIC.
	70 % SiO_2	60 % SiO_2 50 %	SiO_2 40 % SiO_2
Lavas.	Rhyolite. Trachyte. Andesite.		
Tuffs.	Rhyolite. Andesite-rhyolite. Andesite.		
Hypabyssal.	Quartz-porphyry and granophyre. Porphyry. Porphyrite. Quartz-dolerite. Dolerite.		

The rocks mentioned in the table show a decreasing percentage of silica moving from left to right, but as unfortunately it has not been possible to make more than one analysis, the silica percentages in the above table can only be regarded as approximate. It will be seen that no basic volcanic rocks are represented, for it is not known whether the serpentine outcrops which occur in several localities in the Peninsula should be classed as lavas or intrusions, but there is little doubt that the serpentine is a basic member of the Pahang Volcanic Series. If further field-work shows that the serpentine outcrops all occur at the boundary of Raub and Gondwana rocks, as seems to be the case in Negri Sembilan*, it will be clear that the serpentine is an altered lava.

Rhyolites.

Rhyolite lavas have been found in situ at Pulau Chengai and Lubok Plang on the Pahang River, and as derived water-worn boulders embedded in tuff on the railway at Kuala Tekal (Pl. XXIX, Fig. 2) and at the 105th mile, and in the Pahang River at Pulau Guai, Lubok Plang, and Pulau Chengai. In addition there are many rocks which may be altered rhyolites exposed in the valley of Sungei Kechau. The lava in situ at Lubok Plang is in layers, one layer being entirely spherulitic and another showing phenocrysts of felspar and quartz set in a fine-grained crystalline groundmass. There is a good deal of secondary quartz in the rock and a flow-structure is very pronounced in the groundmass, which contains unaltered bands of spherulites, and curved lines marked by opaque secondary material in the remaining finely crystalline part of the groundmass probably indicate that the whole of it was once spherulitic. The rhyolite boulders in the ashy boulder-beds here are very similar to the rock in situ.

Certain boulders in the ashy boulder-beds of Pulau Guai are of rhyolitic lava containing numerous inclusions of shale. For the most part the non-porphyritic portion of the rock is finely crystalline, but here and there the remains of spherulites can be distinguished, and although it has undergone considerable alteration, yet a well-marked flow-structure can still be seen. Probably the groundmass originally was a glass. The quartz phenocrysts are corroded and contain inlets and inclusions of the groundmass. The orthoclase and oligoclase crystals are altered to an opaque brown material and probably also to calcite, for they contain a considerable amount of that mineral, but the whole of the rock is rich in calcite, and perhaps all of it is derived from neighbouring sediments by infiltration. In addition the rock contains small altered crystals of biotite.

Some of the inclusions of the sedimentary rocks are of dark shale, and one slide showed chiastolite crystals in the shale-inclusions, which differ from the rest of the rock in containing no calcite. Other inclusions were of fine-grained volcanic tuff.

This striking rock is found in situ at Pulau Chengai, but none of the boulders of rhyolite embedded in tuff which are found within 100 yards of it were seen to contain shale-inclusions.

The age of the rhyolite of Lubok Plang is Raub period, for it is associated with Raub rocks, which, however, differ from those of other known localities in including a band of chert.

TRACHYTES.

No very typical members of this group of lavas are known, but some rocks occur between Jeransong and Jerantut which are related to the trachyte family on the one hand and to the andesitic rocks of Tembeling on the other.

One rock is red-brown in colour with numerous tiny iron-stained patches, and looks very much like a compact quartzite in the hand-specimen. It has S.G. 2·64, and contains very scanty small phenocrysts of felspar up to $1\frac{1}{2}$ mm. in length.

Under the microscope the rock is seen to be holocrystalline and to contain these minerals: orthoclase, oligoclase, calcite, and limonite. The orthoclase forms irregular-shaped prisms about $\cdot 03 \times \cdot 01$ mm., and the oligoclase occurs as prisms with a better shape and about the same size. There is a well-marked flow-structure, and a number of the prisms are slightly bent, owing, probably, to movement while they were still hot and plastic. Large crystals of calcite are common, and there are abundant small areas of calcite scattered throughout the rock, interstitial to the felspar prisms, all of it probably having been derived from neighbouring limestones. Limonite as scattered grains is an important constituent of this rock, whereas another rock from $101\frac{1}{2}$ mile is grey in colour owing to the great amount of pyrites which it contains.

Fairly numerous phenocrysts of felspar are set in a groundmass of felspar prisms, and the whole of the rock presents a cloudy appearance under the microscope, due to the presence of abundant secondary white-mica flakes. The phenocrysts are very much altered, being almost entirely obscured by the mica flakes, but certain clear patches in the mica aggregate consist of albite felspar. Some of the felspar prisms in one specimen were orthoclase, and that is the reason for placing the rock amongst the trachytes (it may be a porphyry); the majority of the felspars, however, are albite and oligoclase. It is possible that the albite is a secondary mineral formed by the alteration of a more basic felspar, but this is not probable, for no remnants of the basic felspar are left.

There are cracks in the rock which are lined with small irregular plates of albite, the centre being occupied by a zeolite, which has a spherical form with fibrous structure, the fibres being arranged to radiate from the centre, and in nearly all cases the centres of the spheres lie on the edge of the felspar which lines the cavity walls. The zeolite fibres under crossed nicols extinguish parallel to their length, and have low double refraction and low refractive index, so it is probably natrolite.

The presence of abundant secondary mica with clear albite and natrolite is fairly strong evidence that the original felspar of this rock was more basic, but, as already mentioned, this is not confirmed by any remains of a more basic felspar.

The pyrites occurs as small grains and never has a good crystal form.

Andesites.

They are dark-purple or green-black rocks containing small phenocrysts of felspar which are visible in the hand-specimen. The S.G. usually varies between 2·68 and 2·76, and the following minerals are usually present: porphyritic felspars, augite, groundmass felspars, a black iron-ore (magnetite or ilmenite), and chlorite.

The felspar phenocrysts as a rule are not more than 1 mm. across, and are strongly zoned and often rounded and corroded by the groundmass. Albite twinning is the rule, and the extinction angle never exceeds 18°, usually being about 10°. The crystals are often very much altered, usually containing abundant mica flakes, but the felspars of the Tembeling andesites often consist of merely a thin shell of felspar, enclosing a pale-green central portion made up of a network of chlorite and felspar. In one such phenocryst the albite twinning could still be distinguished. It can be seen in several specimens without chlorite that the outer shell of the zoned felspars is less altered to mica than is the central zone, and it would appear that the striking chlorite-felspar network, which makes up the greater part of the phenocrysts of the Tembeling andesites, was formed by the mica flakes in the felspar being altered to chlorite. The interference colours of the chlorite are usually blue, and the double refraction is considerably less than that of quartz. The smaller felspar phenocrysts have a sharp outline, in contrast to the larger rounded phenocrysts.

The augite is of a very pale-green colour, occasionally occurring as fairly large well-shaped crystals (Pl. XXIX, Fig. 1), but more often the crystals are small (compared with the felspar phenocrysts) and ill-shaped. Sometimes the augite occurs only as tiny grains interstitial to the felspars of the groundmass, and sometimes none at all can be distinguished in the rock, but this does not mean that augite was not at one time present, for such a rock always contains small areas of chlorite, which probably represent augite grains, distributed throughout the groundmass. The alteration of a phenocryst of augite to chlorite can often be seen in an intermediate stage. No rhombic pyroxene could be seen in any of the specimens, and all the chlorite pseudomorphs after pyroxene seemed to have been formed from monoclinic pyroxene.

The felspars of the groundmass often occur as untwinned lath-shaped crystals measuring about ·06 mm. × ·01 mm. with a low extinction angle, corresponding to albite-oligoclase, and a well-marked flow-structure is often present. They are packed so densely together as to leave no room for a glassy residuum. Iron-ores, probably both magnetite and ilmenite, are usually scattered throughout the groundmass, and often occur as inclusions in the border of the large rounded felspar phenocrysts. Chlorite is abundant, and it is clear that it is usually the result of alteration of augite and felspar.

Epidote is common both as a granular alteration-product of augite and felspar and also in thin veins, and calcite is common as in all the Pahang Volcanic Series rocks. It is probably in many cases the result of infiltration from neighbouring sedimentary rocks.

A Tembeling andesite (No. 3756) was analysed by Mr. J. Shelton, Chemist to Geological Department F.M.S.

Examination under the microscope shows that the greater part of the rock is made up of tiny laths of cloudy oligoclase-andesine with interstitial chlorite. The zoned felspar phenocrysts are largely altered to chlorite, iron-ores are abundant, and small grains of augite occur in the rock. A little epidote is present.

SiO_2	59·02
Al_2O_3	17·23
Fe_2O_3	9·07
MgO	2·42
CaO	4·12
Na_2O	4·20
K_2O	1·68
Loss on ignition	2·64
	100·38

The large amount of iron-ores in the rock is indicated in the analysis, as also is the fact that the felspar is of a soda-lime rather than a lime-soda variety.

A lava rather like this, but containing much more secondary chlorite, from the Benta–Kuantan road, contained numerous amygdules, the small ones being spherical and the larger being elongated along the line of flow.

Pseudomorphs of chlorite and micaceous material after olivine are present in two specimens of rocks from the Tembeling district with S.G. 2·68, and in large fragments of lava from a tuff-deposit near Kuala Lipis, S.G. 2·75. Unfortunately nothing is known of the field relations of these olivine-bearing rocks.

The felspar phenocrysts (acid oligoclase) have rounded corners and have been partially resorbed by the action of the groundmass, and they have a border rich in grains of iron-ores. These phenocrysts of felspar may be as much as 4 or 5 mm. in length, but there is a second generation of smaller felspar phenocrysts which are sharper in outline and show no reaction-border.

The groundmass has suffered alteration, and for the most part consists of an irregular mosaic of felspars and quartz, in which can be distinguished occasional tiny felspars about ·05 mm. in length, and abundant scattered granules of dark material, some, and perhaps all, of which is magnetite.

Another type of andesite (S.G. 2·70) containing abundant large phenocrysts set in the groundmass of microliths, can be seen at several places for a distance of about ¼ mile along the railway, near the 117th mile at Tembeling. There are two sets of phenocrysts, one is 2 or 3 mm. across, with occasional crystals as much as 1 cm. across, and the other set varies between 0·1 mm. and 0·3 mm. in length. Most of the phenocrysts are plagioclase showing albite and microcline twinning, and having an extinction angle corresponding to a composition intermediate between oligoclase and andesine. The large phenocrysts are rounded and show dark reaction-borders. The border is part of the groundmass, differing from the greater part of the groundmass in containing a bigger proportion of a brown dust pigment (probably iron-ores) which gives nearly all the Tembeling andesites their dark-purple colour. Some big phenocrysts have a border of a different type. The crystal is filled with an opaque dust, possibly kaolinite, and a binary twinning can be distinguished, indicating that this central part is orthoclase felspar, but surrounding the crystal is a narrow band of clearer felspar which is not in crystalline continuity with the remainder of the phenocryst. Needles of ilmenite are scattered about in the crystal, in the clear band more abundantly than elsewhere.

The groundmass is made up of twinned microliths of felspar, which have a low extinction angle, with a certain amount of interstitial quartz, which is probably the result of devitrification of pre-existing glass. There are abundant iron-ores scattered throughout the rock, much of it associated with chlorite, which was formed by the alteration of augite, for pseudomorphs having the form of augite are the rule. Apatite is a common accessory, and an irregular-shaped grain of a mineral like sphene was seen in the rock.

Andesites are found interstratified with Raub and Gondwana rocks both as lavas and tuffs, and it appears that the andesite phase was predominant during the whole period of the Pahang Volcanic Series.

Quartz-porphyry and Granophyre.

Between the 101st and 102nd mile on the Pahang Railway there is a considerable development of intrusive rocks consisting of quartz-porphyry and granophyre. They probably belong to the same period of eruption as the rhyolites of Lubok Plang, a few miles to the east, and contributed to the formation of certain fragmental deposits in the neighbourhood by adding more acid material to what would otherwise have been andesite tuffs and breccia. The rocks are associated with intrusions of a more basic composition, both dolerite and porphyrite.

About 10 miles further north there are extensive exposures of granophyre both in the river and the railway cuttings, and there is a strong development of quartz-porphyry near the railway near Sibah and Lanna. Other exposures occur along the Benta–Kuantan road and in the valley of the Kechau River.

Quartz-porphyry.

The rock consists of felspar phenocrysts, quartz phenocrysts, chlorite, and iron-ores probably formed by the alteration of augite, apatite, a fine-grained holocrystalline quartz-felspar groundmass, and secondary minerals. Its specific gravity varies between 2·57 and 2·75.

The felspar phenocrysts are most commonly of a plagioclase with composition between oligoclase and andesine, but orthoclase is usually present in less quantity. Occasionally there are two sizes of felspar phenocrysts, all being altered, either to kaolin or to a micaceous mineral. The quartz crystals are practically always corroded by the groundmass. Augite is rarely seen in the quartz-porphyries, but they usually contain pseudomorphs of chlorite associated with magnetite, whose form resembles basal sections of augite, and one rock contains light-brown augite with lamellar twinning. Apatite is a very constant accessory and is often very abundant.

The most common secondary minerals are calcite derived in part from neighbouring sedimentary rocks and epidote. Some of the calcite is an alteration-product of the felspar. A dark-green fibrous mica has been noticed occasionally. The groundmass is usually a holocrystalline fine-grained granitic mosaic of quartz and felspar in which sometimes microlites of felspar can be detected, and occasionally a microspherulitic structure is present, while some quartz-porphyries have a granophyric groundmass, and thus form a link with the granophyres next to be described.

GRANOPHYRE.

The granophyres are exposed in the Pahang River for a distance of 2 miles upstream from Pulau Guai, 2 or 3 miles above 111th mile on the railway, and with the quartz-porphyries of the 101st mile on the railway. The exposures in river and railway all occur on a line of strike running about N. 10° W. by S. 10° E., and the intrusion may be quite narrow, but if continuous its length is over 10 miles.

It is usually white in colour, and all the specimens that have been collected have a specific gravity of about 2·60. Under the microscope, particularly between crossed nicols, these rocks present a beautiful appearance. Quartz phenocrysts and phenocrysts of orthoclase and oligoclase make up a large portion of the rock. Biotite mica is sometimes present, and apatite and pyrites are constant accessories. Of secondary minerals calcite is the most common, and one specimen has felspar phenocrysts containing abundant flakes of chlorite.

A lava with traces of granophyric structure occurs just below the mouth of the River Chika, interstratified with Gondwana rocks, but near the boundary of the outcrop. It may be of the same period of eruption as the granophyre intrusions, which would therefore be assigned to the period of deposition of the oldest Gondwana rocks, but the fact that tuffs which are interstratified with Raub rocks contain granophyre fragments shows that the period of intrusion of some of the granophyre was Raub.

Reference has already been made to the boulders of dark-coloured quartz-porphyry which lie scattered about on the Main Granite Range. They occur at the Ginting Sempak* road at the 11¼, 17th, 20½, 22½ miles, and at several places going down the Pahang side of the pass, also on the way to Ginting Bidei* from Klang Gate*, both as boulders and in situ, and as a single boulder near the 8th mile Rawang road*.

In the hand-specimen white phenocrysts of felspar and quartz can readily be distinguished, the dark-purple or black groundmass having a compact homogeneous appearance, and under the microscope it is seen that the felspar varies from oligoclase to labradorite and that it is often strongly zoned, the kernel being more basic than the exterior zones. The felspar and quartz are angular in outline and sometimes rounded. A little uralitized augite is an occasional constituent, suggesting a connexion with the granite-porphyry next to be described. Well-shaped crystals of biotite are common, often very much altered to chlorite with the separation of iron-ores, and very often they have been bent by shearing movements which have imparted a flow-structure to the groundmass, these same shearing movements in all probability being responsible for the angularity of the quartz and felspar crystals. The groundmass, in those specimens which have not been sheared, is that typical of a quartz-porphyry or rhyolite, and occasionally it is made up of microspherulitic structures. Some specimens much resemble tuffs, but no fragments of lava have been observed in them, and their tuff-like appearance is probably due to brecciation by shearing movements.

From the uniformity in the appearance of quartz-porphyry both in the hand-specimen and under the microscope, when examined as boulders in the different localities above described and in situ, it seems to be clear that the rock is an intrusion and not a lava, and this view is supported by the total absence of any appearance of stratification or variation when traced through the 100 feet or so of thickness of rock which is exposed at Jeram Gading*. It was not possible to go more than ¼ mile upstream from the point in the River Seli* where the quartz-porphyry was first encountered in situ, and the extent of the outcrop is unknown, but from the rocks exposed downstream it appears that the quartz-porphyry was intruded into cherts, grits, and quartzites, and is therefore of a later age than the other intrusions of the Pahang Volcanic Series.

The granite-porphyry also referred to in the account of the distribution of the Pahang Volcanic Series is not definitely proved to belong to the series, but it is usually associated with the purple quartz-porphyry, and its occurrence at Ginting Sempak* and Ginting Bidei* suggests that it was lifted to form the caps of those hills by the intrusion of the granite, and that it is therefore older than the granite.

The hand-specimen is always green in colour, and is apparently composed of a mosaic of quartz and felspar of uniform grain with also abundant flakes of biotite, but under the microscope the rock is seen to be markedly porphyritic. The phenocrysts are felspar, varying from oligoclase to labradorite, quartz, biotite, both rhombic and monoclinic pyroxene, with smaller quantities of black iron-ores, apatite, zircon, and blue tourmaline, and the groundmass is a perfectly clear mosaic of quartz and felspar (oligoclase to labradorite), which has sometimes the appearance of micropegmatite.

The phenocrysts of felspar and quartz usually have an irregular form and are encroached upon by the groundmass. The form of the zoning of some of the felspar phenocrysts shows that, after they were formed, they were reduced to a mere fraction of their original dimensions, and a phenocryst was noted with one end altered to an aggregate of mica flakes, the aggregate extending on one side much beyond the present boundary of the felspar crystal and yet containing no small blebs of quartz corresponding with those of the groundmass. It is clear that the phenocrysts have been resorbed by the groundmass, but after consolidation, the action being probably the result of shearing movements. The biotite is deeply pleochroic and is of a deep brown colour. Some of the crystals are bent, like the biotite crystals in the quartz-porphyry last described, but some of it is not distorted in any way, and from this, and the very irregular outline, it is concluded that some of the biotite is secondary.

The pyroxene is in colourless, poorly shaped crystals, and much of it is certainly a monoclinic variety, but some crystals showing longitudinal cleavage extinguish straight between crossed nicols and are therefore a rhombic pyroxene. The interference colours in slides where quartz sometimes gives pale yellows vary between wide limits, for both the monoclinic and the rhombic pyroxene, from grey of the first order (like quartz) to brilliant blues and greens of the first order. The pyroxenes are altered to two distinct products, one appearing in section as a thin strip surrounding the crystals, made up of small fibres of green mica, set diametrically across the strip, and thin bands having this composition sometimes penetrate the augite and the quartz and felspar too. The other alteration-product is a pale-brown chlorite of mica in plates and flakes which replace the greater part of the crystal. In some specimens some of the pyroxene crystals have been completely replaced by the alteration-product, while in others the pyroxene is left quite fresh.

From the specimens examined it appears that since consolidation the rock has been affected by considerable earth movement resulting in a complete reconstitution of the groundmass, the partial brecciation of the crystals, and the formation of biotite.

It is probable that a trip further upstream beyond Jeram Gading* will show this granite-porphyry in situ, for boulders of pebbles of the rock are very common there. From the description of the rock it is clearly a metamorphosed igneous rock—the granulitic groundmass, the brecciation of the crystals, the puckering of the original altered biotite, and the interstitial nature of the other rich brown biotite all indicate that it has been formed from an igneous rock by intense shearing movements. Although many of the boulders of the rock in the River Seli* and on the flanks of the Ginting Bidei* hill are many yards across, yet no exposures clearly in situ were seen.

Occasionally small patches of a finer-grained material are enclosed in the rock, which when examined under the microscope are found to differ from the rest of the granite-porphyry only in their finer grain. Apart from these few patches, the rock is remarkably constant in grain as well as in composition, and considering that it is known to occur intermittently as large boulders over an area of 100 square miles this is perhaps one of its most striking features.

Boulders of schist, made up of hornblende, augite, and felspar, were collected from the same locality, and one less metamorphosed specimen contains altered fragments which reveal that the original rock, from which the schist was formed, was a porphyritic igneous rock. The three minerals are confined more or less to individual bands, with a thickness sometimes reaching ¼ inch. The hornblende is a green pleochroic fibrous variety, and the augite is light-brown in colour, occurring like the felspar in granules. The felspar is orthoclase. The specimen mentioned above, which has been less highly metamorphosed, does not show a foliated structure. It is made up of sheared oligoclase-andesine felspars set in a fine-grained groundmass which contains scattered fibres of hornblende and large patches of augite and secondary quartz. A similar rock occurs in situ in the belt of schists fringing the Kuala Lumpur plain, associated with gneisses made up for the most part of secondary micas and quartz in which remain "eyes" of felspar or quartz phenocrysts that have resisted shearing. It is not proposed to do more than mention these rocks, though they are certainly older than the granite and are probably members of the Pahang Volcanic Series.

Porphyrite.

Near the 101st mile on the Pahang railway there is a good exposure of an intrusive rock which is markedly porphyritic, no quartz however occurring as phenocrysts. In one exposure the rock has a pink-white colour, with light-green phenocrysts of felspar ranging up to 1·5 cm. in length, and in a neighbouring exposure the rock is grey in colour with white phenocrysts. The specific gravity of the first rock is 2·55, whilst that of the second is 2·62—the increase probably being solely due to the large amount of iron-pyrites which is present in the grey rock.

The phenocrysts are of basic oligoclase or andesine with a very ragged outline, and lie in a granitic groundmass of oligoclase-andesine, felspar, and quartz.

The groundmass consists of a fairly cross-grained mosaic of badly formed crystals of plagioclase and possibly too of orthoclase, of length averaging 0·5 mm., with some finer-grained mosaic. Quartz is present, some of it perhaps being primary, and there is abundant secondary mica with also a little chlorite.

Dolerites.

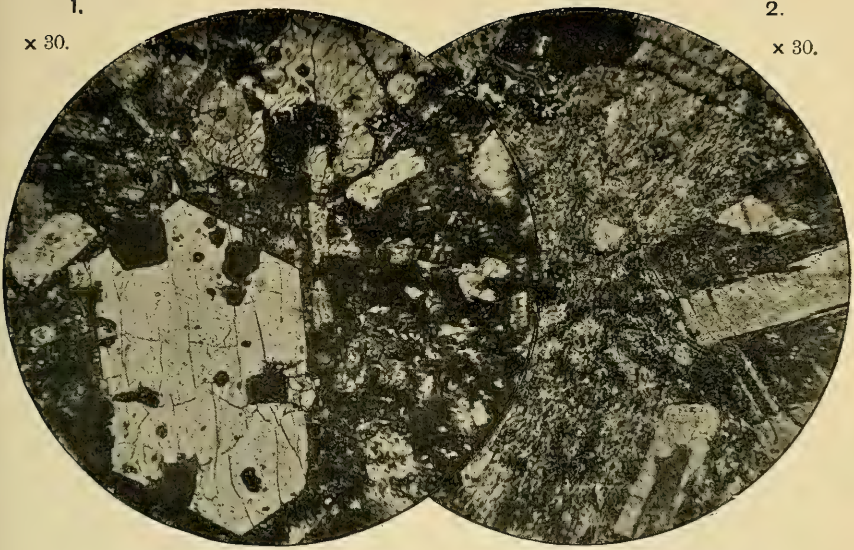
Intrusions of dolerite were seen in only two cuttings of the Pahang Railway, namely at the 101st mile, where the rock is a fine-grained quartz-dolerite like a lava, and at the 104½ mile, while none were seen on the Pahang River between Kuala Lipis and Mengkarak. However, they are known to occur at several places along the Benta–Kuantan road, in the zone of the Pahang Volcanic Series.

At the 101st mile the quartz-dolerite is in contact with quartz-porphyry. The relations of the two rocks were not determined, but it was clear that the quartz-porphyry was intruded into inter-bedded ashes and shales.

At the 104½ mile the dolerite is associated with shales, tuffs, and andesitic lava, and some of the tuffs near here contain water-worn boulders of volcanic rocks which will be described later. The dolerite at the 104½ mile is considerably altered, the hand-specimen being a dark-green rock containing occasional phenocrysts of augite up to ½ cm. or more in length with prisms of altered plagioclase, some of which has extinction angle corresponding to oligoclase-andesine. The felspars have ophitic structure with regard to a green mineral which has been formed as a result of the alteration of augite, and there are some fragments of augite still remaining. A little of the green mineral is chlorite, but most of it is an amphibole, some of it of a fibrous habit, and some of it replacing the augite crystal for crystal. There is a considerable quantity of ilmenite present.

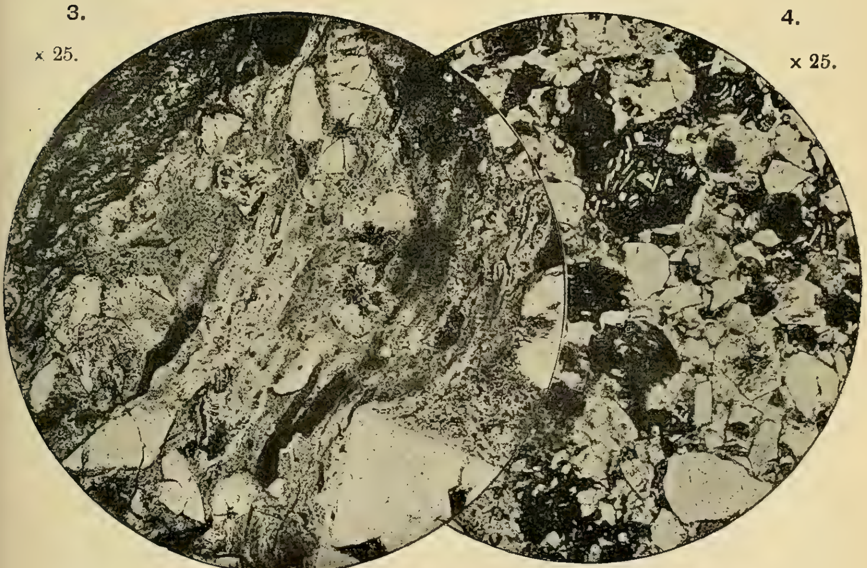
1. × 30.

2. × 30.



3. × 25.

4. × 25.



J. B. Scrivenor, photo.

ROCK-SECTIONS, PAHANG VOLCANIC SERIES, F. M. STATES.

The rock at 101st mile differs in that it is fine-grained; it contains interstitial quartz, and all the augite has been altered to a chloritic mineral. It contains a good deal of calcite, possibly derived from the decomposition of the felspars, which enclose numerous white mica flakes, and it also contains abundant ilmenite.

There are a number of dolerites known in the Peninsula which are of a considerably later period of eruption. In some cases the intrusion occurs in quartzite, and is therefore probably of later age than the Gondwana Series, in other cases still the dolerite dykes penetrate the Mesozoic granite, and the latter, like many acid intrusive rocks which penetrate the granite, are not included in the Pahang Volcanic Series.

There are other intrusions of doubtful age where the field evidence is not sufficient to assign them definitely to one of the two groups. The dolerite of Batu Bersawah * gold-mine in Negri Sembilan, which is intrusive into Raub shales and limestones, is veined with calcite and has been much sheared, so there is no doubt that it belongs to an early period of eruption, for it is probable that the only extensive shearing movements in this district took place at the time of the intrusion of the Mesozoic granite. The rock is much weathered, the ferromagnesian mineral being completely altered, and chlorite, pyrite, and ilmenite partly changed to leucoxene are abundant.

A rock with ophitic structure occurs in two localities along the road * from Kuala Lumpur to Bentong as a band about two yards wide in phyllites at the 17½ mile, and in a high cutting 250 yards short of the 21st mile as a band in contact with sheared chert and within a few yards of a large devolopment of felspathic grits. It was seen by Mr. Scrivenor in 1907 as lenses between chert bands exposed in the road-cuttings which were newly made at that time, suggesting that the rock is a pillow-lava. Mr. Scrivenor collected chert specimens from near the 17th mile also in 1907, but weathering has since destroyed the freshness of the exposures.

The rock at the 17½ mile is dark-grey and finely crystalline, made up of good-shaped narrow prisms of felspar about ¼ mm. long, with a low extinction angle corresponding to oligoclase, and poorly shaped crystals of hornblende of the same size. There is nearly as much hornblende as there is felspar, and it is noteworthy that the felspars have a better crystal shape than the hornblende. Occasionally there is a larger and broader phenocryst of oligoclase with length of nearly 2 mm. There is a little apatite and a little quartz as interstitial grains. Abundant cubes and grains of pyrites are disseminated throughout the rock, probably all of it secondary, and veins and streaks made up of fibrous serpentine or chlorite, quartz, and an opaque fine-grained dust also make up a considerable proportion of the rock.

Many specimens of the rock near the 21st mile have been examined, very similar in texture and colour to the above in the hand-specimen. Felspar prisms, like those described above, make up the same proportion of the rock, but there is a total absence of hornblende, the spaces intervening between felspar prisms being filled with serpentine or chlorite, quartz, ilmenite skeletons, and calcite. There are no porphyritic felspars and no apatite was observed. Some pyrites is present. Veins of fibrous serpentine or chlorite penetrate the rock and there are also veins of calcite.

The evidence is all in favour of the volcanic rocks at the 17½ and 21st miles being identical, the one near the 21st mile having suffered considerable alteration. The felspars in both rocks are partially obscured by an opaque dust, but the extinction angles can be measured in many cases, and there is no doubt that these correspond to oligoclase. There is no sign that the felspar was originally a more basic variety that has undergone albitization, but the association of the volcanic rock with chert at once suggests that the latter owed its origin to the fact that the sea-water was highly charged with silica derived from pneumatolytic gases which were given off by the volcanic rocks. These same gases may have attacked the basic felspar of the volcanic rocks, turning it into a more alkaline variety, and at the same time releasing some of the calcium as calcium carbonate. Under these conditions radiolarian organisms flourished and their siliceous remains dropped to the sea-bottom and there formed beds of chert. However, no proof has yet been obtained that the felspar of the rocks was originally more basic.

Greenstones.

In early reports[1] certain "greenstones" were often referred to which are probably all members of the Pahang Volcanic Series, in which chlorite, epidote, and calcite have been developed by weathering. It is sometimes difficult to distinguish whether they are tuffs, lavas, or intrusive rocks, and probably all three occur, but their relationship with the series as a whole is easily recognized.

Serpentine.

Serpentine occurs in Perak*, Pahang, and also in Negri Sembilan*, but its relation to the Pahang Volcanic Series is not yet known, though, as it is known to be strongly sheared in Pahang and in one of the Negri Sembilan* outcrops, it is probably of pre-granitic age. An outcrop at Bersiah* in Upper Perak* contains olivine, but the indications are that the serpentine of all the other outcrops was formed by the alteration of amphibole. The four known outcrops in Negri Sembilan* seem to occur at the boundary of Raub and Gondwana rocks, but as this fact has not been definitely proved it is useless to theorize about its significance. There is little doubt that the serpentine is an altered lava or intrusion of Pahang Volcanic Series age.[2]

EXPLANATION OF PLATES XXIX AND XXX.

Plate XXIX.

Fig.
1. Augite-andesite, 41st mile, Benta–Kuantan road. × 30 diam.
2. Olivine-andesite, Kuala Teh, Pahang Railway. × 30 diam.
3. Quartz-porphyry with flow-structure, Ginting-Sempak. × 25 diam.
4. Andesite-rhyolite breccia, 47th mile, Benta–Kuantan road. × 25 diam.

(*Photographs by J. B. Scrivenor.*)

Plate XXX.

Map[3] of Pahang Volcanic Series, Federated Malay States.

[1] These are alluded to in the Ulu Pahang Memoir, p. 41.
[2] This article is published by permission of the Geologist, F.M.S.
[3] The Map (Plate XXX) will appear with the second part of this paper in the November Number.

(*To be concluded in our next Number.*)

IV.—A System of Petrography.

By S. J. Shand, D.Sc., F.G.S., University of Stellenbosch, South Africa.

The recent paper by A. Holmes on "A Mineralogical Classification of Igneous Rocks"[1] is an attempt to settle a matter which English-speaking petrologists ought to have tackled long ago. There seems, however, to be a disposition, on the part of British geologists especially, to leave the matter alone in the fond belief that some "natural" system of classification will presently be revealed to us whereby all our taxonomic doubts and difficulties will be dispelled. Nothing can be more unreasonable. The philosophic treatment of a subject must follow, not precede, the preparatory work of discriminating, sorting, and docketing; and the sharper the discrimination, the more thorough and orderly the sorting and docketing, the easier to make the philosophic digest. Hitherto petrographers have not discriminated well; we have not done our sorting in a methodical way; we have tied on labels in the most haphazard fashion; our house is in a state of dreadful confusion. It is true that through all the disorder we have caught fascinating glimpses of regularities and relationships; of connexion between this and that; but the deplorable fact appears that we are unable to test or verify any hypothesis, or to take a single confident step towards the philosophic treatment of our subject, until we put our house in order. We have got to do our sorting and docketing all over again, and do it methodically, and then only can we begin to look for the philosophy of the matter.

I have already taken in this journal what I consider to be the first step in the process of bringing order out of confusion—I refer to the separation of five prime divisions of igneous rocks on the basis of the degree of saturation of their constituent minerals.[2] I should in the near future have tried to indicate some further steps in the same direction, but I wished to present a complete scheme, with illustrative examples, and this, with the imperfect facilities of a Colonial university, has taken much time. Now that Mr. Holmes has broached the question, however, I think it ought not to be allowed to drop until some understanding is reached, and I wish therefore to submit an alternative system in very brief outline.

Holmes adopts my five saturation classes as the basis of his arrangement, and then effects a first subdivision within each class by means of a cross-classification in which the orthoclase-albite ratio is put against the albite-anorthite ratio. In arriving at the former of these ratios he proposes to calculate the felspathoids, micas, and analcite into their equivalent amounts of orthoclase and albite. Following upon this he makes the historic separation of plutonic rocks from dyke-rocks and lavas; and to establish still smaller subdivisions he suggests (but does not elaborate in his paper) the employment of the colour ratio (felsic-mafic ratio) and the texture, in that order.

[1] Geol. Mag., March, 1917, p. 115.

[2] Geol. Mag., November, 1913, p. 508; November, 1914, p. 485; August, 1915, p. 339.

In the classification adopted by Iddings[1] there are also five primary groups, characterized respectively by (1) quartz in excess, (2) quartz and felspar, (3) felspar with little or no quartz, (4) felspar and felspathoid, (5) felspathoid without felspar. Within each of these groups Iddings employs a cross-classification in which the colour ratio (expressed simply by the terms leucocratic and melanocratic) is put against the ratio of alkali- to lime-bearing felspars. The next subdivision is based on crystallinity, only two groups, phanerocrystalline and aphanitic, being recognized; and further splitting is effected on grounds of texture, or preponderance of a particular mineral, or for other trivial reasons.

Now I am with Holmes in adopting the degree of saturation as the basis of classification; with Iddings in desiring to give increased prominence to the colour ratio; with Iddings also in preferring a twofold to a threefold division with regard to crystallinity; and with both of them in recognizing the necessity of yielding to the old-established practice of distinguishing potassic from sodic and calcic rocks on the basis of the felspars which they contain. I differ from both Holmes and Iddings regarding the treatment of felspathoids and in certain other minor matters.

I propose to apply the various taxonomic factors in the following order:—

1. Degree of saturation, giving five divisions.

2. The double ratio of Or-Ab-An, giving about eight families within each division.

3. The colour ratio,[2] giving from two to ten, but preferably four groups in each family.

4. Crystallinity, giving two sub-groups within each group.

5. Ratios of specific minerals or groups of minerals, giving the types to which "specific" names will be attached.

6. Trivial characters of mineralogy and texture, giving varieties.

I shall discuss the application of these factors very briefly.

1. Regarding the employment of the degree of saturation as the basis of the system I have nothing to add to what I have already written. It furnishes five sharply distinguished divisions, as follows:—

(1) Oversaturated rocks [O].
(2) Saturated rocks [S].
(3) Undersaturated rocks.
  (*a*) Dyad and triad metals unsaturated [u].
  (*b*) Monad metals unsaturated [U].
  (*c*) Both monads and dyads unsaturated [W].

2. The distinction of potassic from sodipotassic and sodic rocks, judged by the ratio of orthoclase to albite, is deeply ingrained in petrography. Iddings has tried to make the distinction quantitative by introducing the limiting ratios of 5 : 3 and 3 : 5, or 37·5 per cent

[1] *Igneous Rocks*, vol. i, 1910.
[2] *Journ. Geol.*, 1916, p. 400.

and 62·5 per cent. It has to be recognized that strict application of these limits is difficult in some cases, as for example where the felspar is soda-orthoclase or microperthite, but we ought not to be contented with any lower degree of precision than that which these three subdivisions afford. To be strictly logical we ought to use the Or-Ab ratio only for leucocratic rocks, employing a lime-magnesia-iron ratio in the same way for melanocratic rocks, but this would involve a great departure from existing nomenclature and is better left alone at present.

A new point is introduced here by Holmes' proposal to calculate felspathoids and micas into their equivalents of orthoclase and albite for the purpose of classification. I am unable to accept this proposal, partly because it takes us away from the actual composition of the rock and partly because in many cases it must be impracticable and its results misleading. That this is not too severe a view the following considerations will, I think, show:—

(1) Natural leucite always contains a variable quantity of soda.

(2) Natural nephelite, as recently shown by Bowen,[1] holds from 10 to 35 per cent of a plagioclase molecule and from 15 to 30 per cent of kaliophilite.

(3) Rock-forming micas may hold lithia and soda as well as potash, and alumina may be replaced by iron.

(4) The proportion of a mica is extremely difficult to estimate accurately, whether geometrical methods or heavy liquids are employed. The scales tear away in making sections, and they do not give a clean separation with liquids.

I cannot see how the first three of these difficulties can be overcome unless every mineral is analysed as well as weighed.

It is simpler, and it avoids all possibility of misrepresentation, to use the ratio of

(orthoclase + leucite) : (albite + nephelite + sodalite, etc.)

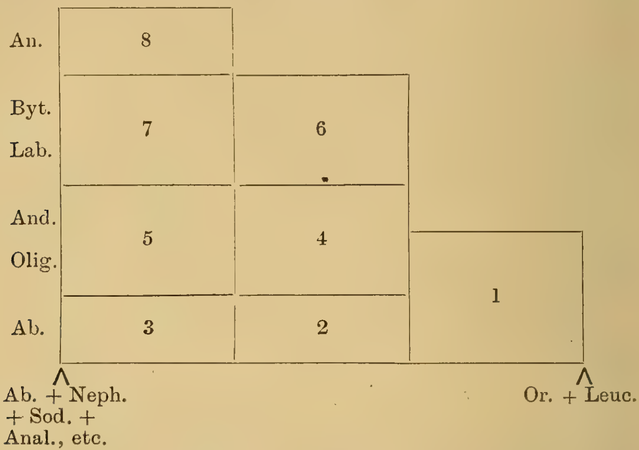
without any modification, and with the usual limiting values of $\frac{5}{3}$ and $\frac{3}{5}$. The difference between this procedure and that of Holmes is important. Holmes aims at an expression of the ratio of potash to soda; but for the reasons already advanced his statement will rarely be quite true, and may be seriously untrue, unless each mineral is analysed separately. I, on the other hand, am content to state the ratio of the essentially potassic minerals orthoclase and leucite (with whatever dissolved molecules they may hold) to the essentially sodic minerals albite, nepheline, sodalite, etc. (with their dissolved molecules). Holmes uses an unreliable norm: I prefer the plain truthfulness of the mode.

3. As regards the albite-anorthite ratio which is to be crossed with the above, custom has drawn loose lines of division between albite and oligoclase and between andesine and labradorite. Holmes makes the matter more precise by drawing the lines at 15 and 50 per cent of anorthite. Here again, while recognizing the difficulty of adhering strictly to these limits (as, for example, when the

[1] *Amer. Journ. Sci.*, February, 1917.

felspars are zonally built), I am for aiming at the highest attainable precision. For completeness we ought to make another boundary at 85 per cent of anorthite, for rocks rich in anorthite deserve special recognition just as much as the albitic ones. This is not a new line of division, for it has been customary in the past to distinguish between gabbro and eucrite.

Putting now the Or-Ab ratio against the Ab-An ratio, we establish a number—which is theoretically twelve but practically only eight—of families within each of our saturation divisions. The general scheme will be the same for each division, as follows:—



In order to indicate the contents of each of these family-compartments I shall confine my attention for the present to the holocrystalline rocks. Divisions are indicated by means of the letters O, S, u, U, and W, and the "family" names employed in each division show by means of a prefix or suffix the division to which they belong. Thus all names of saturated or oversaturated rocks end in *-ite*; those of U-rocks in *-oid*[1]; names of u-rocks may carry either the prefix *sub-* or the suffix *-ole*; and for W-rocks the prefix *sub-* will be used in conjunction with the suffix *-oid*. Where a name is put in brackets it is to suggest that a new name is required.

O 1, granite; 2, ekerite; 3, (albite-granite); 4, granodiorite; 5, tonalite; 6, granodolerite; 7, (quartz-gabbro); 8, (?).

S 1, syenite; 2, laurvikite; 3, (albite-syenite); 4, monzonite; 5, diorite; 6, (orthoclase-gabbro); 7, gabbro; 8, eucrite.

u 1, subsyenite; 2, sublaurvikite; 3, (?); 4, submonzonite; 5, subdiorite; 6, (?); 7, subgabbro; 8, subeucrite.

U 1, (syenoid); 2, laurvikoid; 3, (foyaoid); 4, monzonoid; 5, essexoid; 6, (?); 7, theraloid; 8, eucroid. (*Alternatively*, U 1, 2, 3, syenoid; 4, 5, dioroid; 6, 7, 8, gabbroid.)

W 1, subsyenoid; 2, sublaurvikoid; 3, (subfoyaoid); 4, submonzonoid; 5, subessexoid; 6, (?); 7, subtheraloid; 8, subeucroid. (*Alternatively*, W 1, 2, 3, subsyenoid; 4, 5, subdioroid; 6, 7, 8, subgabbroid.)

[1] Trans. Geol. Soc. Edin., 1910, p. 376.

4. We have next to attend to the colour-ratio—that is, the ratio of the heavy, mostly dark-coloured minerals to the light, mostly pale-coloured minerals. The really important point about them is of course their density, but the colour is a convenient mark of it. I have already proposed the use of a set of prefixes to indicate this character.[1] I would go further than this, and actually give different names to rocks with conspicuously different values of the colour-ratio. This is already done sometimes, as in the following cases:—

orthoclasite ⟶ syenite ⟶ shonkinite ⟶ perknite
anorthosite ⟶ gabbro ⟶ (picrite) ⟶ pyroxenite, etc.
alaskite ⟶ granite ⟶

To make such a distinction quantitative, it would accord fairly with existing practice if we fixed the boundaries at 3, 50, and 97 per cent of heavy minerals. In the oversaturated division it is obvious that the melanic end-member of each family would be a quartz-perknite. In the S and U divisions it would be a pyroxenite or hornblendite. In the u and W divisions the corresponding end-member would be a peridotite or cromaltite.[2] All the varietal names required for the more minute description of these are already in existence. For the leucocratic end-members too it will rarely be necessary to find new names, since nearly all cases are already covered by such names as orthoclasite, albitite, oligoclasite, anorthosite. It is mainly for the third group, containing from 50 to 97 per cent of heavy minerals, that new names analogous to shonkinite will be required. Owing to the similarity of the end products, the total number of distinct groups will not be 8 × 4, but practically about 20 in each division. The four groups in each family may be distinguished by the letters L, l, m, and M where suitable names are not at present in existence.

5. As regards crystallinity, I have a decided preference for the *two* groups of Zirkel (and Iddings) as opposed to the three groups of Rosenbusch (and Holmes). As everybody knows, there is no special set of characters which one can postulate of a so-called dyke rock—not even that it occurs in a dyke. Some dyke rocks have all the characters of plutonics, others all those of lavas. There are in fact only two sets of cooling conditions which produce really significant differences in the characters of the rocks formed under them; these conditions are slow cooling with a sufficiency of fluxes and rapid cooling with diminished content of fluxes: that is, plutonic and effusive conditions, giving rise to phanerocrystalline and aphanitic rocks respectively. If it is desired to express the actual manner of occurrence of a rock mass, it can be done by means of a prefix attached to the name, as dyke-granite, dyke-rhyolite, and so on. A tinguaite I would describe as a dyke-phonolite, a grorudite as a dyke-ekerite or microekerite, a vogesite as a dyke-shonkinite, a hedrumite as a micronordmarkite, etc. In this way a great number of superfluous names might be eliminated and others reduced in value from group names to mere varietal names.

[1] *Journ. Geol.*, 1916, p. 400.
[2] Melanite-pyroxenite: Trans. Geol. Soc. Edin., 1910, p. 376

The names of the *aphanitic* subfamilies in this system ought of course to be drawn from existing names of lavas, just as those of the phanerocrystalline rocks have been derived from existing names of plutonic rocks, and the same set of prefixes and suffixes may be used to signify the degree of saturation, thus: andesite, subandesite; latite, sublatite, latoid, sublatoid; and so on. A certain amount of redefinition of names will be necessitated, and a number of new names will be required. It is not proposed to coin these in advance: it is better that the supply should wait upon the demand. In the meantime it is always possible to describe any rock by means of its co-ordinates in the system, thus: O 3 L 2; S 7 1 1; u M 1, etc.

6. With five divisions, about twenty effective groups in each division, and two subgroups within each group, we have already distributed all known igneous rocks into about 200 compartments. Within each of these compartments there is still room for considerable variation as regards both the minerals themselves and their proportions. A further use of the colour-ratio prefixes, l_5 to l_9 and m_5 to m_9, makes it possible to describe variations in quantity of light and dark minerals. In the same way we may express different degrees of oversaturation by means of prefixes, O_1, O_2, O_3, etc. It will still be necessary to discriminate between different mineral associations. Compartment U 2, for example, holds both leucite-albite rocks and nepheline-orthoclase rocks, and these will certainly require different "specific" names. Again, in the u division we find rocks with unsaturated magnesium and others with unsaturated calcium; and in W the melilite rocks (for melilite holds soda as well as lime and magnesia) form a distinct facies. It is therefore to be expected that from 300 to 500 "specific" names will be required in all. These should be supplied, of course, partly by the readjustment of existing names and partly by the coining of new ones as the need arises. Still further subdivision is possible on a basis of texture; but it is the writer's opinion that differences of texture, other than the one fundamental difference already considered, should be expressed by prefixes or descriptive adjectives, not by the coining of new names.

It will be noticed that no place has been found in this system for the order of crystallization. This is one respect in which it is to be hoped that the system may in future suffer modification. In the meantime the discrepancies between theory and observation are so great that it would only be misleading to give to this factor any place in systematic petrography.

In conclusion, let me say that I do not claim for the system elaborated above that it is either a "natural classification" or a final one, or that it will enable one to dispense with chemical analysis. It is nothing more than a system of indexing, based as far as possible on *significant* mineralogical data treated quantitatively. It lays down lines along which the naming of rocks should proceed, and fixes sharp boundaries which no rock-name should transgress if it is to be more than a mere sack-name. The coining of unacceptable new names is largely avoided by the use of simple prefixes and suffixes, and where existing names have been used their connotation has been narrowed but not radically altered. A thorough reformation of petrographic system is urgently called for, and it is felt that the scheme now presented affords a great increase of precision and significance at the cost of the smallest possible rearrangement of ideas. I do not wish to compare this system more closely than I have already done with those of Iddings and Holmes, but it is my hope that English-speaking petrologists will awaken to the necessity of themselves testing these and any other propositions that may be forthcoming, and of coming to some agreement regarding the exact meaning of the terms they use. There is room for wide differences of opinion, but "the dust of controversy—what is it but the falsehood flying off?"

REVIEWS.

I.—A Gigantic Eocene Bird.

The Skeleton of *Diatryma*, a Gigantic Bird from the Lower Eocene of Wyoming. By W. D. Matthew and Walter Granger. Bull. Amer. Mus. Nat. Hist., vol. xxxvii, pp. 307–26, pls. xx–xxxiii, 1917.

So long ago as 1874 Professor Cope gave an account of some fragmentary remains of a very large bird from the Lower Eocene of New Mexico, referring it to a new genus and species under the name *Diatryma gigantea.* Since that time a few additional fragments have been described by various writers, but it was not until last year that the discovery of the greater part of a skeleton in the Bighorn basin of Wyoming made it possible to get any clear idea of the structure of this remarkable creature. This specimen has now been described and figured and its affinities discussed by Messrs. Matthew and Granger in the memoir referred to above.

Diatryma is now shown to have been a ground bird of great size, standing some 7 feet in height and possessing a relatively very large head and vestigial wings. It was not a "Ratite" in the usual sense of the word, but like *Phororhacos*, to which it has much superficial resemblance, was a highly modified Carinate, most of its peculiarities resulting from its loss of the power of flight. The skull, as in *Phororhacos*, is of extraordinary size, measuring about 17 inches in length and being largely made up of a great compressed beak 9 inches long by 6½ high. The tip of the beak is not decurved as in *Phororhacos*, and the small sharply defined nostrils are situated rather nearer the ventral than the dorsal border of the beak and some 2 inches in front of the orbit, which seems to have been incomplete below. The supra-temporal fenestra is closed below by the union of the postorbital with the squamosal. The quadrate has a single transversely expanded head with two imperfectly separated facets for articulation with the squamosal. The jugal is stout and its anterior end unites with the maxilla much above its ventral border. The vertebræ are short but massive, especially in the cervical region. The ribs are wide and thin, with little or no trace of uncinate processes. The sternum is unknown. The shoulder-girdle is more like that of a Ratite than that of a normal Carinate, the coracoid and scapula being almost in the same straight line instead of making a sharp angle with one another; the coracoid is short and broad. The humerus has undergone great reduction and is in much the same condition as in the Cassowaries; the structure of the rest of the wing is unknown. The pelvis is remarkably short in front of the acetabulum, but is long and wide posteriorly; the ilium and ischium are co-ossified, and the pubis, which is in contact with the ischium, unites with it for a short distance. This pelvis is not at all like that of a Ratite bird, but is said to resemble that of *Cariama*. The bones of the hind limb are completely adapted for a pedestrian gait, and probably the adaptive characters have completely masked any that might throw light on the relationship to less specialized forms.

The authors discuss the possible relationship of *Diatryma* to other birds. They dismiss, probably quite rightly, the idea of any near affinity with the later *Phororhacos*, but at the same time suggest a relationship with *Cariama*, apparently on rather slender grounds. They conclude that "probably *Phororhacos* is a derivative of some extinct Eocene type of normal adaptation allied to the Eocene ancestors of *Cariama*, while *Diatryma* would be a derivative of normal Cretaceous Euornithes, allied perhaps more closely to the ancestral line of *Cariama*".

From inspection of the photographs alone, it is perhaps rash to offer any suggestions, but several points in the structure of the skull seem worthy of notice. From the figure it appears that there was probably a well-developed fronto-nasal hinge such as is especially well developed in the Parrots; the supposition that such a joint existed seems to be supported by the condylar form of articulation of the pterygoid and palatine. Again, the closing of the supratemporal fossa below occurs in many Parrots, and small, sharply defined narial openings also occur in some members of that group, as the authors point out. The form of the jugal and the manner of its union with the maxilla is also parrot-like. On the other hand, in Parrots the orbit is usually closed below, while in *Diatryma* it remains open, at least apparently so. A simple-headed quadrate, very similar to that of *Diatryma*, occurs in *Stringops*, which is regarded by Fürbringer[1] as the most primitive type of Parrot, although its primitive characters are obscured by later specializations, while the group, as a whole, is considered by the same writer as a very ancient one. Of course, the form of the bones of the hind limb of *Diatryma* appears to be against any relationship with the Parrots, in which the hind limb has become modified to form a highly specialized climbing and grasping organ, but possibly in the early members of this group these characters had not been acquired, and *Diatryma* may have originated from some such unspecialized form. The earliest fossil Parrot which is definitely known is *Psittacus verreauxii*, Milne-Edwards, from the Lower Miocene of the Allier, France; in this the climbing type of hind limb was already fully developed.

[1] *Journal für Ornithologie*, 1889, p. 236; also *Untersuchungen zur Morphologie und Systematik der Vögel*, p. 1285 et seqq.

Marshall[1] states that remains of Parrots occur in the Eocene of Wyoming, but I have been unable to find any warrant for this statement.

CHAS. W. ANDREWS.

II.—NEW CRETACEOUS GASTROPODA. BY BRUCE WADE.

A NOTABLE contribution to the palæontology of the Cretaceous Mollusca has recently been published in the Proceedings of the Academy of Natural Sciences of Philadelphia, vol. lxviii, pt. iii, for 1916–17 (pp. 455–71, pls. xxiii–iv), under the title of "New Genera and Species of Gastropoda from the Upper Cretaceous", by Bruce Wade. The paper is descriptive of a number of elegant shells in a remarkable state of preservation, some having colour as though freshly taken from the sea. The material was collected at Coon Creek, in the north-eastern part of the Nairy County, in west-central Tennessee, from an horizon in the lower part of the Ripley formation. With such excellent material as a basis, several new generic types have been described, and the results will be helpful to those who are familiar with similar shells from other areas, and cognizant therefore of the necessity for the establishment of new divisions. Seven families are represented among the forms described, and there are nine new genera and eleven new species. *Mataxa elegans* is the type of a new genus of the Cancellariidæ; and among the points of difference from *Cancellaria* are the development of a canal, the lack of conspicuous cancellate sculpture, and a less acuminate spire. *Mataxa* includes Stoliczka's *Narona eximia*, from the Cretaceous of Southern India, and is probably near the recent sub-genus *Massyla*. To the Volutidæ are assigned two new genera, *Tectaplica* and *Drilluta*. *Tectaplica* is considered as one of the most primitive of the Volutes, and as ancestrally related to *Volutilithes*, from which it differs in having a shorter spire, with flat sides not interrupted by pronounced shoulders. *Tectaplica simplica* is the genotype. The new name *Drilluta* is a contraction of the names *Drillia* and *Voluta*, and the genus includes a group of Volutes that have been variously described under these names and also under *Fasciolaria* and *Fusus*. The absence of a posterior siphonal notch and the presence of columella plaits distinguish this new genus from *Drillia*, while a lower spire and numerous transverse folds can be noted as points of difference from the typical *Voluta*. *Drilluta* is separated into two well-defined groups: section A (type, *D. communis*, sp. nov.) and section B (type, *D. major*, sp. nov.). The Fusidæ are represented by a new sub-genus *Anomalofusus*, and *Ornopsis*, gen. nov. The new sub-genus resembles *Phos*, but is much more slender, and it differs from *Fusus* in its shorter canal and its thickened and notched outer lip. *Fusus* (*Anomalofusus*) *substriatus* is the type. *Ornopsis glenni* is the type of a genus that bears resemblance to *Latirus* in general outline, and to some of the Buccinidæ in its close compact spire. *Hydrotribulus* (type, *H. nodosus*, sp. nov.) is a new genus, assigned to the Buccinidæ,

[1] *Zoologische Vorträge*, "Die Papagaien," p. 45, Leipzig, 1889.

characterized by a low spiral angle, strong cancellate sculpture, a much inflated body, and by a much excavated and reflected inner lip, which conceals an umbilicus. It has a general resemblance to *Pyrifusus*, and includes a species from the Senonian of Aachen, referred by Müller to the genus *Rapa*, and by Holzapfel to *Tudicla*. Referred to the Euomphalidæ is a shell that has a flattened spire, a deep wide umbilicus, of which the outer margin is conspicuously produced, and an angular peripheral margin. It shows points of resemblance and difference both with *Discohelix* and *Straparollus*, and a new genus, *Hippocampoides* (type, *H. serratus*, sp. nov.), is instituted for it. Representatives of the Turbinidæ and Delphinulidæ are also described. A new genus, *Schizobasis*, is assigned to the former, and the genus *Urceolabrum*, also new, to the latter. *Schizobasis depressa* is the type of a turbiniform genus that is characterized by a short well-defined canal, a feature not found in any other members of the Turbinidæ. A conspicuous circular reinforced aperture, a deep umbilicus, and an elevated cancellate spire are characters that typify *Urceolabrum tuberculatum*, gen. et sp. nov., the genotype of a well-defined group of forms new to the Delphinulidæ. To this new genus is also referred a form described by Müller from the Aachen Beds as *Scalarta*, and afterwards by Holzapfel as *Liotia*.

III.—The Silurian Inlier of Usk. By C. I. Gardiner, M.A., F.G.S.; with a Palæontological Appendix, by F. R. C. Cowper Reed, M.A., D.Sc., F.G.S. Proceedings of the Cotteswold Naturalists Field Club, vol. xix, pp. 129–170, pls. vii and viii and Geological Map.

The general structure of the inlier consists of two anticlines with a N.N.E.–S.S.W. trend separated from each other by a fault, having the same general direction. The western, or Coed-y-paen, anticline is more important than the eastern, or Llangibby, anticline and brings the Wenlock Shale (the lowest exposed rock) to the surface over a large area. The Wenlock Limestone comes in at a somewhat indeterminate horizon, which is probably not quite the summit of the Wenlock Shale, and over this the Ludlow rocks lie conformably. There is no typical Downtonian, but the basement bed of the Old Red Sandstone overlies the Ludlow with very little discordance in dip. The rocks of the Llangibby anticline as seen at the surface belong almost entirely to the Ludlow series, and only at one place is the Wenlock Limestone exposed; however, three small inliers of Old Red Sandstone are brought in by minor synclines.

Only on the south and west of the Coed-y-paen anticline does the Old Red Sandstone overlie the Ludlow rocks directly; on all other sides wherever it can be seen the boundary of the inlier is a faulted one. The chief of these faults, like that dividing the two anticlines, have a N.N.E.–S.S.W. direction; but there is also another series of faults in a more or less E.–W. direction which are later than the first-named series. These systems of faults must be referred to the Pennine and Armorican foldings respectively, as they affect the Old Red Sandstone as well as the Silurian.

The rocks in this area present quite normal characters; the Wenlock Shale is 850 feet thick, and is composed of mudstones below with sandy shales above, at the base of which the characteristic calcareous concretions are found. Towards the summit it becomes more sandy and passes into the Wenlock Limestone. This rock is only 40 feet thick here and is composed of thin limestone bands with sandy partings, and cannot be called a coral reef. It occurs in isolated strips as it is much broken by the faulting, and has even been pushed into the more yielding shale beds.

The Ludlow Beds are 1,300 feet thick; they pass downwards conformably into the underlying Wenlock, and are composed of impure sandy shales followed by sandstones. There is no Aymestry Limestone nor any sign of the Aymestry fauna, and the Ludlow rocks cannot be divided into an upper and lower series. This great thickness of Ludlow Beds at Usk shows a striking contrast to the Tortworth inlier, where they have been in great part removed by erosion.

In the appendix by Dr. Cowper Reed several new species and varieties are described, including new species of *Chonetes* (*C. ceratoides*), *Pteronitella* (*P. inexpectata*), *Gosseletia* (?) [*G.* (?) *Tawneyi*], *Pholadella* (*P. McCoyi*), and new varieties of *Proetus Stokesi*, Murchison, and *Phacops Stokesi*, Milne Edwards.

The paper is illustrated by a geological map and two plates of photographs of the fossils described by Dr. Cowper Reed.

W. H. Wilcockson.

IV.—Atlantis. By Pierre Termier. Smithsonian Report for 1915, pp. 219–34.

In this publication, which is a translation of a lecture given before the Institut Océanographique of Paris on November 30, 1912, the author puts forward the evidence in favour of accepting the Platonian account of the destruction of Atlantis as materially true. After giving a general account of the old legend, with quotations from Plato's *Timæus*, the author reviews the geological and zoological evidence for the former existence and recent disappearance of the Atlantic Continent. He argues that land must have existed along the lines of the Alpine and Hercynian folds, and also further south along the northern border of the old Gondwanaland, and that this land must have gradually foundered, the old E.–W. lines giving place to the present N.–S. line, as shown by the bank which runs from north to south down the centre of the Atlantic Ocean. This bank, and the similar banks off the coast of Africa, are connected with volcanic and seismological phenomena as shown by the volcanic islands which are situated on them; and the deeps on either side of it bear the same relation to the volcanoes as do the deeps off the western coast of America to the Cordillera of the Andes. The presence of undisturbed Miocene beds in the Azores and Canaries shows that land existed in the neighbourhood of these islands in Miocene times, but the writer regards as the chief point in favour of recent submergence the fact that a cable ship in 1898 dredged up some fragments of tachylyte from the sea bottom about 500 miles north of the Azores. This, he says, must have solidified on the surface of the land, as it would have solidified at least into a crypto-crystalline condition at the depth of 3,000 m. where it was found. This fact, coupled with the great inequality and rocky character of the ocean floor at this spot, where the ooze only lies in the hollows, shows that the submergence must not only have been recent but also sudden, as there had been no time for the inequalities of the surface to be eroded.

Turning to the zoological evidence, the author quotes work by M. Louis Germain to show, firstly, that the terrestrial fauna of the Azores, Madeira, the Canaries, and Cape Verde Islands is of continental origin, and shows evidences of adaptation to desert conditions. Secondly, that the Quaternary formations of the Canaries and Mauretania contain the same species of *Helix*. Thirdly, that the mollusca of the four archipelagoes have affinities with the Tertiary mollusca of Europe; and, fourthly, that the Oleacinidæ group of pulmonate mollusca is confined to the Mediterranean basin, the Azores, Canaries, Madeira, the West Indies, and Central America. All this evidence seems to demand the existence of a continent connecting Europe and Central America which gradually disappeared, beginning with the westerly portions and leaving the easterly portions till the last, and the author considers that it is quite conceivable, if we take into account the unstable condition of the Atlantic volcanic areas, that the final disappearance may have been witnessed by man, and have been so sudden as to constitute a "cataclysm".

W. H. Wilcockson.

V.—The Earthquake in the Marsica, Central Italy. By Professor Ernesto Mancini. Smithsonian Report for 1915, pp. 215–18.

On January 13, 1915, the Marsica, a district in the southern part of the Aquilian Abruzzi, was devastated by a very severe earthquake. The region of the Marsica which was the epicentre of the disturbance is situated on the line along which, according to the Japanese seismologist Professor Omori, the chief earthquakes in Italy have been distributed. The district is essentially sedimentary and of Karstic origin, so that a volcanic origin is impossible, and the shock seems to have been caused by two separate deep-seated movements which took place either simultaneously or in very quick succession along a line having a north and south trend, some sixty or seventy miles east of Rome. The shock was of such intensity that the seismograph at Rocca di Papa was dismounted, as also would have been the instrument at Rome had it not been provided with special stop screws. The details of the seismic waves have been worked out by Professor Oddone. Their period was 0·7 second, their wave-length 20 metres, and their amplitude 20 centimetres. The damage to buildings was caused by a bulging movement of the ground, accentuated by eddying motions due to the combination of longitudinal and transverse vibrations coming from the hypocentre to the epicentre at the surface.

The number of victims is estimated at 25,000, at Avezzano 10,700 being killed out of a total population of only 13,000.

W. H. Wilcockson.

VI.—La Ligne de Depressions Regna-Verin et ses Sources Carbonatées. By P. Choffat. Extrait du tome xii des Communicações do Serviço Geológico de Portugal. Lisbon, 1917.

The Gallaico-Durian massif of the North of Portugal is traversed by a curious line of depressions, with which are associated a considerable number of mineral springs particularly rich in carbonates. The country rock consists of Pre-Cambrian schists and Cambrian sediments, both being penetrated by granites, supposed to be of Hercynian age. Although the evidence is not very clear, the springs probably have some genetic connexion with the fractures that determine the lines of depression.

R. H. Rastall.

VII.—The Economic Geology of the Central Coalfield of Scotland. Area VIII: East Kilbride and the Quarter. Mem. Geol. Surv. Scotland. pp. iv+52, 1 fig. and 2 plates, 1917. Price 2*s*.

This is the second memoir of a series of which the first was recently noticed in these columns (Geol. Mag., September, 1917, pp. 426–7). It follows precisely the same lines as its predecessor, and contains an interesting account of the strata of the East Kilbride district, which are mostly of Lower Carboniferous age, resting on the plateau basalts. Only at the extreme east of the area is there a small patch of Upper Carboniferous rocks. The very fine sections in Calderwood Glen are described in detail, and special attention is paid to the discovery first made by Mr. Carruthers that here plants of undoubted Calciferous Sandstone age are associated with *Posidonomya Becheri* and *Aviculopecten papyraceus*, thus showing that in Scotland the Pendleside facies occurs very low down in the Lower Carboniferous. At the present time the economic productions of this area are of small value, and the interest is mainly stratigraphical and palæontological.

R. H. R.

VIII.—Molybdenum in Natal.

In the *South African Journal of Science* for November, 1916, Mr. A. L. du Toit describes a curious occurrence of molybdenum ores in a sandstone belonging to the upper part of the Karroo system (Molteno Series). The molybdenum minerals occur as an impregnation in quite a limited area, in association with iron pyrites and marcasite and some carbonaceous material. The minerals that have been identified are molybdenite, molybdic ochre, and ilsemannite, the two latter being apparently oxidation products of the sulphide. The origin of the deposit is not clear: it does not seem to be detrital, as the patch is well defined from the rest of the rocks; there are no dykes or any indication of channels by which solutions could have ascended. About 100 feet higher in the Molteno Series is a dolerite sill of the usual Karroo type, and the mineralization may possibly be due to this phase of igneous activity.

R. H. R.

IX.—A remarkable occurrence of Calcite in Silicified Wood. By Edgar T. Wherry. Proceedings of the United States National Museum, vol. liii, pp. 227–30.

In 1915 Mrs. Charles D. Walcott collected in the Yellowstone National Park a piece of silicified wood of *Sequoia magnifica* (Knowlton), in which were numerous white grains with rhombic crystal outlines and dark central inclusions. When thin sections of the wood were examined the grains were found to consist of calcite, occurring sometimes in simple crystals, but more frequently twinned, often polysynthetically. The development of the crystals shows some interesting features. In the centre there is generally an inclusion of woody cells, distorted either very little or not at all, then comes a layer of clear calcite with woody fibre which occasionally extends along the boundaries of the twin lamellæ; outside this, just within the crystal, there is often a zone of disrupted cells, and finally outside the boundaries of the faces, which are often curved, is a dark compact band of tissue. The fibre round the crystals shows little or no distortion, each cell being filled with a single quartz crystal; this shows that the calcite must have been deposited before the quartz and when the wood was so rotten that pressure was not transmitted through it for any distance.

The history of the specimen seems to have been as follows:—The rotten wood was permeated by solutions containing calcium carbonate, which at first deposited calcite quickly at certain places round the cells. Then, later, deposition became slower and the cells were pushed outwards by the growing crystals to form the dark band round the edges. After a break in the deposition a final layer was deposited so as to include some of the broken tissue on the edges of the crystals, and finally the calcareous solutions gave place to siliceous solutions which deposited quartz in the remainder of the tissues.

W. H. Wilcockson.

X.—The Royal Society Club.

In the *Annals of the Royal Society Club, the record of a London dining-club in the eighteenth and nineteenth centuries* (Macmillan, pp. xv, 504, 1917, price 18*s*. net) Sir Archibald Geikie has published a volume packed with biographical interest. Although such a book can at best be but a record of fact, still there is a certain amount of general interest within these covers. From various accounts one gathers that almost from 1650 certain members of the future Royal Society (1662) met together at taverns to discuss their interests, but the earliest surviving document relating to the "Club" dates from October, 1743. Since then the weekly dinner regularly continued for sixty years, and the most curious portion of these records consists in the bills of fare faithfully entered up week by week for more than forty years of the eighteenth century. Further interest will be found in the names of and notes on the numerous geologists, both British and foreign, who were admitted as guests to the dinners, with the curious un-British arrangement that they had to pay for their own food.

The book demanded wide knowledge and reading, and there are but few slips. Huxley died in 1895, Carpenter (p. 402) was W. B., and Horsley died in Mesopotamia. The statements on p. 428 are unfortunate.

XI.—Brief Notices.

1.—A Contribution to the Invertebrate Fauna of the Oligocene Beds of Flint River, Georgia. By William Healey Dall. Proc. United States Nat. Mus., vol. li, pp. 487–524, with pls. lxxxiii–viii, 1916.

In this work the author recognizes two zones, an upper and a lower. The former has yielded 61 species, of which 29 are new, while the lower zone has furnished 39 species, among which 9 are new. Five of the new species and 14 of the others are said to be common to both zones. A useful distribution table is given of the fauna showing the occurrences of the various species in both zones and their presence in the Ocala, Vicksburg, Orthaulax, and Chipola horizons. The fauna described is entirely molluscan, comprising Pelecypoda, Gasteropoda, and Scaphopoda.

2.—Mollusks from the type locality of the Choctawhatchee Marl. By Wendell C. Mansfield. Proc. United States Nat. Mus., vol. li, pp. 599–607, pl. cxiii, 1916.

The fauna here described is made up of Pelecypoda, Gastropoda, and Scaphopoda, having been collected in the Choctawhatchee Marl, regarded as of Miocene age, occurring near Redbay, Walton County, Florida. Descriptions and illustrations are given of the following new species of Pelecypoda: *Arca* (*Scapharca*) *staminea*, Say, new sub-species *rubisiniana*, *Leda choctawhatcheënsis*, *Phacoides* (*Pleurolucina*) *choctawhatcheënsis*, *Astarte* (*Ashtarotha*) *Vaughani*, and *Diplodonta waltonensis*. The complete fauna of this deposit is tabulated so that the range of the species is shown from Oligocene to Pliocene times.

3.—The Shells of the Holderness Basement Clays. By Alfred Bell. *The Naturalist*, 1917, pp. 95–8, 135–8.

This paper furnishes a revision of the published lists of Mollusca from these deposits, with criticisms and remarks on the determinations and nomenclature. Of the 180 molluscs recorded, it is stated that at least 100 are no longer living south of the Shetlands, while the remainder mostly belong to Arctic Norway. Relationships of the Mollusca are noticeable in the Bridlington and Chillesford Beds.

4.—New Meteorites.

Mr. George P. Merrill in the Proceedings of the United States National Museum describes two new meteorites. The one (vol. li, pp. 525–6) is interesting because it was dredged up from Lake Okechobee, Florida, by a fishing net, and may possibly be a fragment of a meteorite which fell in that region about thirteen years ago. The stone is still firm and shows the characteristic crust. Under the microscope the chondritic nature of the stone is at once evident. Altogether the various fragments secured amount to about 1,100 grams. The other meteorite (vol. lii, pp. 419–22) consists of three fairly complete individuals and a fragment, and weighed altogether 7,605 grams. It is of the usual chondritic type, but the finer details of the structure are obscured by oxidation. It was found near Plainview, Hale County, Texas.

OBITUARY.

ALFRED NICHOLSON LEEDS, F.G.S.

Born March 9, 1847. Died August 25, 1917.

(WITH A PORTRAIT, PLATE XXXI.)

We regret to have to record the death of Mr. Alfred N. Leeds, one of the most successful pioneers in the modern methods of collecting and preserving fossil vertebrate skeletons. For nearly half a century he had devoted his leisure to recovering the remains of fossil reptiles and fishes from the brickfields in the Oxford Clay near Peterborough; and the thoroughly scientific and painstaking nature of his work can be appreciated at once by a glance at the unique series of specimens which he contributed to the Geological Department of the British Museum (Natural History).

The second son of Mr. Edward Thurlow Leeds, of Eyebury, Peterborough, Alfred Leeds was born in his ancestral home seventy years ago. He was educated at the Warwick Grammar School, and afterwards desired to follow a medical career; but circumstances necessitated his assuming the management of the Eyebury farm, and from 1868 onwards this was his daily occupation. His elder brother, Mr. Charles E. Leeds, who was then studying at Oxford, received encouragement from Professor John Phillips to persevere in the collection of fossils round his home which he had already begun. A large part of a Plesiosaurian skeleton which he had discovered was, indeed, described by Phillips in his *Geology of Oxford and the Thames Valley* (1871). Under such stimulus he was soon joined by Alfred Leeds, and the two brothers gradually perfected methods of extracting the skeletons from the soft clay which were more scientific and thorough than had ever been attempted before. By liberal rewards they induced the workmen not to dig up bones themselves, but to send notice of each discovery to Eyebury. One or both the brothers would then disinter the specimens with their own hands, noting the mode of occurrence of every fragment and clearly distinguishing the

Photo, Lafayette.

Yours faithfully

Alfred. N. Leeds

parts of each individual skeleton. Next they cleaned, washed, and pieced together the broken fragments at home; and they kept such exact records that if any parts proved to be missing they were able to return to the place of discovery and very often supply the deficiencies. Some of the larger skeletons, in fact, were so widely scattered that they could only be recovered bit by bit in the course of weeks or months as the clay was worked; but the brothers' records were so well kept that even in these difficult cases the missing parts of most remarkable specimens were eventually obtained.

In 1887 Charles Leeds emigrated to New Zealand, where he died in 1912 (see Geol. Mag., Dec. V, Vol. IX, p. 287). For the last thirty years, therefore, Alfred Leeds worked alone, aided only in the delicate processes of preparing specimens by his accomplished wife and by one of his sons, E. Thurlow Leeds, now of the Ashmolean Museum, Oxford. The scientific value of his results was acknowledged by the Council of the Geological Society in 1893, when they awarded to him part of the Lyell Fund.

Although Mr. Alfred Leeds never ventured himself to write about his discoveries, he soon became well versed in the osteology of the Mesozoic reptiles and thoroughly appreciated most of the novelties which he met with. He handed over all his material, with his own observations, to various specialists who were in friendly communication with him. His collection was thus described by J. W. Hulke, H. G. Seeley, R. Lydekker, C. W. Andrews, and A. S. Woodward, and was also used for reference by O. C. Marsh, G. Baur, and others. Among Dinosaurs he obtained important remains of *Omosaurus* and *Stegosaurus*, and especially fine portions of the skeleton of *Cetiosaurus*, including a fragment of the slender whip-shaped end of the tail like that of the American *Diplodocus*. He was the first to find sufficiently extensive series of *Pliosaurus* to show the true nature of that gigantic marine reptile. He also discovered two closely related new genera, which were named *Peloneustes* and *Simolestes* by Lydekker and Andrews respectively. His wonderful collection of Plesiosaurians and Ichthyosaurians enabled Seeley to determine for the first time the characters of the pectoral arch of these reptiles; and he discovered several growth-stages in the Plesiosaurians as described by Andrews. Among Crocodilians he obtained a unique series of more or less nearly complete skeletons of *Metriorhynchus* and *Steneosaurus*, showing that the former differed from all other known Crocodilians in its complete adaptation to aquatic life, lacking bony scutes, and having the tip of the backbone turned downwards to support a vertical tail-fin as in the Ichthyosaurians. From 1890 onwards all the most important of these specimens were gradually acquired by the British Museum, and an exhaustive *Descriptive Catalogue of the Marine Reptiles*, prepared by Dr. Andrews (with illustrations), was published officially in two volumes in 1910 and 1913.

The fishes discovered by Mr. Leeds were no less important than the reptiles, on account of the manner in which they displayed the separate bones, especially of the head. They include several new species described at different times by Dr. A. S. Woodward. The most striking new genus and species is *Leedsia problematica*, the largest known ganoid fish, probably about 30 feet in length and with a tail (now exhibited in the British Museum) 9 feet in span. Remains of *Mesturus* add much to our knowledge of the Pycnodont fishes; while the bones of *Lepidotus*, *Caturus*, and *Hypsocormus* can be handled and studied almost as in specially macerated modern skeletons. Among sharks, there is the first proof that the fin-spines named *Asteracanthus* and the teeth named *Strophodus* belong to the same fish. Like the reptiles, all the most important fishes are now in the British Museum; but there were enough duplicates of both groups to provide for many other museums, and these are to be found both in this country and in Germany, Austria, and North America.

Those who had the privilege of Mr. Leeds' friendship will always retain happy memories of the hospitality of Mrs. Leeds and himself at Eyebury. He lived in the picturesque fenland farm that was formerly attached to the Abbey of Peterborough, and the thick walls, with a remnant of the moat, were an interesting memento of other days. His museum occupied the attics of the house, and the old farm-office was always filled with boxes of the latest discoveries awaiting preparation. Odd trays of specimens in progress were also kept in sight in other rooms to occupy leisure moments. His interests, however, were by no means confined to his fossil bones. He was alive to the progress of science in all ways, and he took an especially active part in local affairs. His loss, indeed, will be mourned by the whole community.

A. S. W.

MISCELLANEOUS.

The Pliocene Cave at Dove Holes.—Early in August last Professor Boyd Dawkins and Dr. Smith Woodward visited the Victory Quarry, Dove Holes, near Buxton, where Pliocene mammalian remains were found in 1902 in a small cave or fissure in the Carboniferous Limestone (Quart. Journ. Geol. Soc., vol. lix, pp. 105–29, 1903). Although the fissure in question has long been emptied and destroyed, several similar fissures, filled with clay and sand, are still to be seen; but no fossils appear to have been met with in these deposits during the past fifteen years. The foreman and some other workmen who helped to find the teeth and bones described by Professor Boyd Dawkins are still employed in the quarry, and have received every inducement to be watchful for similar discoveries.

Piltdown.—During the past summer Dr. Smith Woodward has spent six weeks, partly in association with Professor Elliot Smith and Major Cromer Ashburnham, in exploring the Piltdown gravel. Large excavations were made round the edge of the original pit in which the remains of Piltdown man were found, and much undisturbed gravel was sifted and carefully examined. Nothing, however, was discovered except one unimportant fragment of the tibia of a deer. The second locality in which the late Mr. Charles Dawson picked up fragments of a Piltdown skull has not yet been identified with certainty, but hopeful inquiries are still being made.

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

ASSISTED BY
PROFESSOR J. W. GREGORY, D.Sc., F.R.S., F.G.S.
DR. GEORGE J. HINDE, F.R.S., F.G.S.
SIR THOMAS H. HOLLAND, K.C.I.E., A.R.C.S., D.Sc., F.R.S., VICE-PRES. G.S.
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PROFESSOR W. W. WATTS, Sc.D. (CAMB.), M.Sc., F.R.S., F.G.S.
DR. ARTHUR SMITH WOODWARD, F.R.S., F.L.S., VICE-PRES. GEOL. SOC.

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. XI.—NOVEMBER, 1917.

ORIGINAL ARTICLES.

I.—On a Boring for Coal at Presteign, Radnorshire.

By T. C. Cantrill, B.Sc. Lond., F.G.S., of the Geological Survey of England and Wales.

IN March, 1912, a short paragraph in one of the London daily papers made the astonishing announcement that several beds of coal had been discovered on the Folly Farm, Presteign, and that boring would be started immediately. The astonishment was due to the fact that on the Geological Survey maps Presteign is represented as surrounded by Silurian and Old Red Sandstone formations, with no rocks of Carboniferous age nearer than the Clee Hills, 20 miles away in Shropshire. Unless, therefore, the Survey maps were wrong, and some unsuspected outlier of Coal-measures had been discovered, the name of the scene of operations was likely to prove prophetic.

While staying at Llandrindod in June following, it came to my knowledge that the proposed boring had not only been begun but had already reached a depth of several hundred feet. I therefore agreed to the suggestion of a resident of Llandrindod, interested in the scheme, that I should take the opportunity of visiting the borehole and reporting on its prospects. This I accordingly did on July 2, 1912, and found that it had been carried down through a series of mudstones, grits, and limestones, to a depth of 540 feet. Silurian fossils were found to be abundant in the rocks at the surface, and were present also in the cores brought up from various depths in the borehole. Yet in spite of my having at once submitted a report to this effect to one of the active promoters, urging him to abandon the scheme, the boring was not only continued to a total depth of 888½ feet, but was followed up by the cutting of a drift for some distance into the foot of an adjacent ridge of Wenlock Shales, Woolhope Limestone, and Upper Llandovery Sandstone.

It is scarcely necessary to say that, so far as the finding of coal is concerned, all these operations were foredoomed to failure, as the Silurian rocks contain no coal.[1]

The site of the boring[2] lies about 170 yards N. 17½° W. of the

[1] There is at least one simple precaution that can be taken by anyone before yielding to the temptation to invest in local coal-mining ventures in districts remote from the coalfields. Let an inquiry be addressed to the Geological Survey Office, Jermyn Street, London. A brief, civil, and possibly useful reply will be obtained at the cost of a penny stamp.

[2] The district is contained in the 1 in. Old Series Ordnance and Geological Map, Sheets 56 N.E. and S.E.; in the 1 in. New Series Sheet 180; and in the 6 in. Map of Radnorshire, Sheet 25 (Herefordshire 10) N.E.

Folly Farm, three-quarters of a mile south of Presteign. From the eastern suburb of the town a lane, turning southward out of the Tenbury road at the County Intermediate School, crosses the railway and rises towards the ridge of Nash Wood and Corton. At the foot of the ridge the lane bends to the south east, climbs the Folly Bank by a diagonal course close to the site of the boring, and soon reaches the summit at the Folly Farm (Fig. 1).

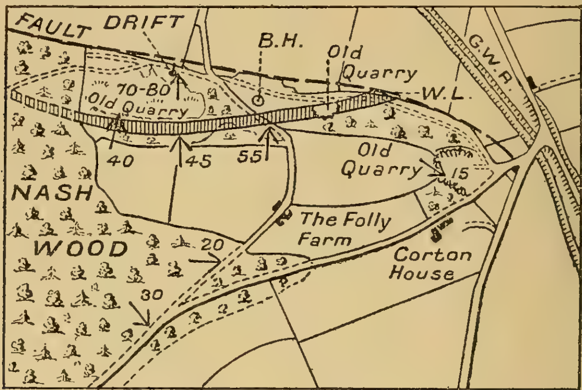


FIG. 1.—Sketch-map of the neighbourhood of Folly Farm, Presteign. Scale 6 inches to a mile. B.H., bore-hole; W.L., Woolhope Limestone.

The mouth of the drift can be seen at the foot of the ridge, about 60 yards west of the bend in the lane, and 140 yards west-by-north of the borehole. The excavation was driven in a direction bearing about S. 16° W., i.e. at right angles to the trend of the ridge, and descends at a slight angle from the horizontal. It thus cuts the beds in descending order at about right angles. Judging by the amount of material brought out, it must have penetrated a considerable distance into the hill-side before it was abandoned through lack of further funds.

Murchison[1] in 1839 sketched the outlines of the geology of Presteign in the classic pages of *The Silurian System*. He clearly perceived the anticlinal structure of the Nash and Corton ridge, and its connexion with the disturbed region of Old Radnor. He saw that the visible core of the ridge is composed of grits and conglomerates, which he correlated with the upper beds of the Caradoc Sandstone of Shropshire, and that these grits rise on each side from beneath a calcareous zone, which he regarded as the equivalent of the Wenlock Limestone. He noted also that the grits contain the characteristic fossils of the upper beds of his Caradoc Sandstone, e.g. *Pentamerus oblongus* and *P. lævis*, and that the overlying limestone, which, on the northern side of the ridge,[2] occurs in the form

[1] *Silurian System*, pp. 313, 314, 321, 322.

[2] This outcrop has been variously referred to as the limestone at the Folly (Murchison), at Folly Bank (J. E. Davis), at Corton (Murchison and W. S. Symonds), and at the Sandbanks (J. E. Davis). It will facilitate description

of nodules and two thin bands subordinate to shale, yielded (to quote the original nomenclature) *Asaphus caudatus*, *Calymene variolaris*, *C. macrophthalma*, and *Isotelus*.

For the most complete geological description of the district the inquirer must turn to a paper read before the Geological Society of London in May, 1850, by J. E. Davis,[1] apparently only a month before the first issue of the Geological Survey map. The purpose of the author was to show that the limestone of Nash and Presteign is of Wenlock age, as had been stated by Murchison in 1839, and not of Woolhope age, as Sedgwick had surmised as a result of a visit in 1846. Incidentally we gather that on the northern side of the Corton ridge the limestone formerly quarried at "the old and now abandoned excavations . . . at the 'Sandbanks'" is about 8 feet thick, is highly crystalline, is separated from the Caradoc Sandstone by a few feet of shale, and is overlain by a greater thickness of Wenlock Shale. He pointed out that the sandstone contains abundant specimens of *Pentamerus oblongus*, Sow., *Atrypa hemispherica*, Sow., and various species of *Orthis*. From the limestone of the Sandbanks he recorded only *Orthis pecten ?*, Dalm., *Lingula quadrata ?*, Eichw., and *Orbicula Forbesi*, Dav. He gave a long list of fossils from the Wenlock Shales of the Sandbanks, and remarked that fragments of *Bumastus barriensis* (Murch.) [=*Illænus barriensis*] occur in great abundance.

The first edition of the Geological Survey map (56 N.E.), undated, but published probably in 1850, showed the Corton ridge as an anticline of "Caradoc Sandstone", with a band of "Silurian limestone" dipping off its northern foot and succeeded by the Wenlock Shale. On a later edition (dated June, 1850, though probably this date refers to the publication of the first edition) the nomenclature is brought up to date, the term "Caradoc Sandstone" being replaced by "Upper Llandovery Rock", while the limestone is definitely referred to as "Woolhope Limestone".

In 1854 Murchison,[2] in his *Siluria*, an abridgment of his earlier work, devoted a woodcut to a longitudinal section of the ground lying between Corton and Presteign. He represented the Caradoc [Upper Llandovery] Sandstone or Corton Grit as dipping steeply northward under a group of shales with subordinate courses of limestone, which he named "Lower Wenlock Shale and Woolhope or Lower Wenlock Limestone". He thus tacitly relegated the limestone to an horizon between the Caradoc and the Wenlock Shales, and definitely correlated it with that of Woolhope. He also noted that the Corton Grit is laden with the casts of *Pentamerus oblongus*. In later editions of the same work [3] he accepted the separation of the

if we call it the Presteign Limestone, or the Presteign outcrop of the Woolhope Limestone. The other outcrop, on the southern side of the ridge, is known as the Nash or Nash Scar Limestone.

[1] "On the Age and Position of the Limestone of Nash, near Presteign, South Wales": Quart. Journ. Geol. Soc., vol. vi, pp. 432–9, with a section, 1850.

[2] *Siluria*, 8vo, 1st ed., 1854, pp. 89, 90, 102, 103.

[3] e.g. in 3rd ed., 1859, pp. 101, 117, 118.

Pentamerus Beds from the Caradoc Sandstone, and adopted the term "Upper Llandovery Rock" for the Corton Grit, in which he noted the occurrence of *Pentamerus oblongus, Atrypa hemispherica, Petraia elongata*, and *P. bina*.

The Rev. W. S. Symonds[1] appears to have been one of the first observers to perceive that the Presteign Limestone is of Woolhope and not Wenlock age. He based this conclusion on the facts that here, as elsewhere, the limestone in question follows immediately upon the "Caradoc" [i.e. the Upper Llandovery], and contains *Illænus barriensis* and *Homalonotus knighti* in far greater abundance than does the Wenlock formation. The same author, in a later and better-known work,[2] remarked that as early as 1850 he had correlated the Presteign Limestone with that of Woolhope by its position with respect to the Upper Llandovery beds and from its containing *Illænus barriensis* in abundance.

Turning now to the current edition of the Geological Survey maps (Sheets 56 N.E. and S.E.), we see that Presteign stands on a great line of faulting, which, ranging in a south-south-westward direction from beyond Church Stretton, runs through Bucknell in the Teme Valley, passes Presteign, and, five miles farther to the south-west, near Old Radnor, brings to the surface the ancient igneous rocks of Stanner, Worsell, and Hanter.

On the western or downthrow side of this fault a broad strip of Old Red Sandstone extends from Bucknell to within a mile of Presteign. Though now cut through by the valley of the Lugg, this strip was once continuous with a second tract of the same formation, which underlies Upper Radnor Wood and Knill Wood, south-west of the town.

On the eastern or upthrow side of the fault, grey calcareous sandy mudstones of the Ludlow formation extend from Brampton Bryan Park to within a mile of Presteign, where they give place to the Wenlock Shales, though these are concealed for a space by the superficial gravels and alluvia of the Lugg. Southward, beyond these valley deposits, the lowest beds of the Wenlock Shales soon emerge along the northern slopes of the anticlinal ridge of Nash Wood and Corton. For a distance of half a mile along the northern foot of this ridge, and dipping northward from it at an angle of 41°, a lenticular outcrop of the Woolhope Limestone comes to the surface at the spot named Folly[3] on the Map (56 N.E.), thinning out to a point, both eastward and westward, between the Wenlock Shales above and the Upper Llandovery Rock below. Immediately south of the limestone outcrop rises the Corton ridge itself, which consists of Upper Llandovery Rock, locally known as the Corton Grit. Several dip-arrows on the map show that the ridge is an anticline. It

[1] *Old Stones*, 8vo, 1855, pp. 59, 60.

[2] *Records of the Rocks*, 8vo, 1872, pp. 139, 140, 160.

[3] On the Ordnance Map, which was published October 1, 1833, this name is placed at the northern foot of the ridge, where the lane from the town begins its diagonal ascent. It may have referred to a cottage shown above the old limestone quarries. The cottage is still remembered by old inhabitants, but the name now applies to the farm on the crest of the ridge.

emerges from the flats of the Lugg near Corton, and trends south-westward under Folly Farm and through Nash Wood toward Nash Scar, where a second outcrop of Woolhope Limestone dips off its southern flank and has till quite recently been quarried and burnt for lime.

From these particulars, which for over half a century have been accessible in the works quoted, it will be seen that a more hopeless district in which to sink for coal could hardly have been found if deliberately sought for. This is not the place to criticize the pseudo-geological statements put forward in support of the scheme; it is sufficient to remark that one of the leading promoters regarded the line of old excavations on the course of the Woolhope Limestone, together with the presence of small pieces of unburnt coal in the soil, as positive proof that the outcrop of a coal-seam had been at some time worked there by opencast.

My hasty visit in July, 1912, and a brief examination made in September, 1915, confirm in all their main features the views expressed by previous observers; but the record of the boring shows that the structure of the ground is not so simple as appears at first sight.

The Corton Grit, consisting of hard and relatively durable conglomerates, grits, and sandstones, forms the dominant feature of the landscape. The rock has been extensively quarried at the eastern end of the ridge, where a large excavation, 100 yards north of Corton House, shows 30 or 40 feet of massive grits and coarse grey sandstones. Quartz and quartzite pebbles are present, and in some cases are claret-coloured. The dip (E.S.E. at 15°) shows clearly the pitch of the anticline. A rotten fossiliferous band about half-way up the western face yielded '*Petraia*' *elongata* (Phill.). In the lane that ascends the Folly Bank, past the boring, to the Folly Farm, excellent exposures show a northward dip of 55°; others, a few yards farther south, and within 70 yards of the site selected for the boring, yielded specimens of '*Petraia*' *elongata* and casts of *Pentamerus oblongus*, J. de C. Sow. On the southern side of the ridge the same lane again shows the grits with *Pentamerus*, dipping first eastward, and then south-eastward, at 20° to 30°.

The Woolhope Limestone has been at some time extensively quarried and burnt for lime along the northern foot of the ridge. The works had evidently been abandoned before the appearance of J. E. Davis's paper in 1850; but the quarries are clearly marked on the Ordnance Map of 1833. As traces of several small earthen kilns of horse-shoe shape can still be detected among the excavations, the presence of pieces of coal in the soil is not to be wondered at. Though little of the limestone is now visible, the old openworks west of the lane show that the bed cannot exceed, if it attains, 12 feet in thickness, that it follows close upon the Corton Grit, and is succeeded by mudstones referable, apparently, to the Wenlock Shales. The high southern side of the excavation affords a fine view of the grit, with large bare bedding-planes, dipping northward at 40° to 45°, and studded with quartz-pebbles of the size of peas. A specimen of *Favosites* was extracted from one of these beds.

In the hollow left by the removal of the limestone only one small exposure of that rock is now visible. It shows about a foot of light-grey crystalline limestone, somewhat nodular and concretionary, and apparently sheared and disturbed, overlain by 6 feet of olive-green mudstones, containing flattened nodules of blue-hearted tough argillaceous limestone, and dipping northward at 20°. These mudstones with nodules evidently form the base of the Wenlock Shales.

These basement-beds are again well-exposed at the western end of the openwork, where they yielded a few fragments of graptolites, identified as of the *Monograptus colonus* or *M. dubius* type by Miss G. L. Elles, who suggests that the beds are not Wenlock but Lower Ludlow; though how this can be so is difficult to explain, since the beds are within 10 feet of the top of the Woolhope Limestone. Higher beds are to be seen at the mouth of the drift (Fig. 1), where they dip northward at 70° to 80°, and yielded *Phacops caudatus* (Brünn.), *Plectambonites transversalis* (Wahl.), and crinoid ossicles.

The materials brought out from the drift show that the beds cut through are the Wenlock Shales, the Woolhope Limestone, and the Upper Llandovery Sandstone, as might have been expected. No other rocks were seen on the tips, though it is possible, as will appear later, that Archæan rocks were reached. A specimen of shale collected from this debris by Professor E. J. Garwood shows a graptolite, which has been identified by Miss Elles as *Monograptus flemingi* (Salt.); another graptolite she suggests is *M. vulgaris*, Wood, or *M. dubius* (Suess). A piece of calcareous grit yielded *Petraia* sp. Unfortunately the drift descends at a slight angle from the horizontal, and in September, 1915, was derelict and full of water. It was therefore impossible to make any examination or measurements of the beds cut through, and no particulars appear to have been recorded while the exploration was in progress.

From the details given above the identity of the rocks as Silurian is put beyond doubt. But the structure of the ground is revealed more clearly by the record of the boring than by the surface exposures. There is, however, strong suggestion of faulting in the manner in which the outcrop of the Woolhope Limestone along the northern side of the ridge comes to an end both eastward and westward. The outcrop commences abruptly about 120 yards north-west of the old Corton quarry (Fig. 1). It then runs obliquely up the ridge through an old overgrown limestone quarry, crosses the Folly Farm lane, and then traverses the long openwork already described till it reaches the eastern boundary of Nash and Caen Wood, where the quarrying seems to have stopped. But the strike of the beds exposed at the western end of the openwork would carry the limestone outcrop down the slope again towards the foot of the ridge, where an attempt appears at some time to have been made to reach it by shafts, one of which can be seen just within the northern edge of the wood some 200 yards to the north-west. It is therefore probable that the disappearance of the limestone in each direction, after a course of only 800 yards, is due, not to thinning out, but to faulting. This supposition is confirmed by the evidence of the boring.

The boring (Fig. 2), which was begun on April 9, 1912, and abandoned in the following autumn, is situated on the Wenlock Shales, a few yards north of the outcrop of the Woolhope Limestone. The following is the complete record as furnished by the firm who carried out the work; for the classification and grouping of the beds and for notes in square brackets the responsibility is mine:—

BORING FOR COAL AT FOLLY FARM, PRESTEIGN.

New Series 1 in. Ordnance Map, Sheet 180 (Knighton); 6 in. Map, Radnorshire, 25 N.E.; Geological Map (1 in.), 56 N.E.; lat. 52° 15′ 54″, long. 3° 0′ 2″. Boring commenced April 9, 1912, abandoned before October 7, 1912. Dip 55°, decreasing downward to 20°.

	Thickness. ft.	in.	Depth. ft.	in.
Wenlock Shales:—				
1. Yellow clay [sandy, full of stones]	11	6	11	6
2. Soft yellow grey shale	3	6	15	0
3. Soft grey shale	2	0	17	0
4. Grey shale and hard balls	12	6	29	6
5. Grey shale	0	3	29	9
Woolhope Limestone and Shales:—				
6. Grey limestone, broken [*Woolhope Limestone*]	20	3	50	0
7. Grey shale with hard balls of limestone	4	4	54	4
Upper Llandovery Sandstone:—				
8. Hard red grit with soft joints	1	8	56	0
9. Red-grey sandstone with lime and white pebbles	10	0	66	0
10. Red-grey sandstone with pebbles and vertical joints	10	6	76	6
11. Red-grey sandstone with shale and pebbles	17	6	94	0
12. Reddish-grey sandstone	4	0	98	0
13. Reddish-grey sandstone with pebbles and pieces of grey shale	6	0	104	0
14. Reddish-grey sandstone and pebbles	10	6	114	6
15. Grey shaly sandstone and pebbles	10	6	125	0
Longmyndian (?):—				
16. Red-grey sandstone with pebbles and beds of green-grey sandstone	10	0	135	0
17. Red-grey sandstone with white joints	6	6	141	6
18. Hard red-grey sandstone with white joints	1	0	142	6
19. Soft grey sandstone	5	0	147	6
[*Fault*]				
Wenlock Shales:—				
20. Soft grey shale	7	6	155	0
21. Grey shale with spar veins	9	0	164	0
22. Grey shale with white spar veins [*Phacops longicaudatus* and *Monograptus*]	46	6	210	0
23. Grey shale with spar veins	10	0	220	0
24. Grey shale with spar veins and partings	5	6	225	6
25. Grey shale with white spar veins	9	6	235	0
26. Grey shale with spar veins and partings	29	0	264	0
27. Grey shale	6	0	270	0
28. Grey shale with 3 in. bed of sandstone	4	0	274	0
29. Grey shale	9	0	283	0
30. Grey shale with sandstone 1 inch thick	1	0	284	0
31. Grey shale	7	0	291	0
32. Grey shale with black markings	9	0	300	0
33. Grey shale with hard sandstone	16	0	316	0
34. Grey shale with thin beds of grit	11	0	327	0
35. Grey shale with beds of spar	8	0	335	0

	Thickness. ft.	in.	Depth. ft.	in.
36. Grey shale and hard dark-grey grit	6	6	341	6
37. Grey limestone	2	0	343	6
38. Dark-grey limestone and shale partings	7	6	351	0
39. Grey limestone	2	6	353	6
40. Grey shale with dark-grey grit	8	6	362	0
41. Grey shale with veins of spar	20	0	382	0
42. Grey shale	104	0	486	0
43. Grey shale with spar veins	6	6	492	6
44. Soft grey shale	10	0	502	6
45. Grey shale	5	6	508	0
46. Grey shale with spar veins	8	0	516	0
47. Grey shale	12	6	528	6
48. Grey shale, broken	47	9	576	3
49. Soft grey shale	8	3	584	6
50. Grey shale, broken	24	6	609	0
51. Grey shale	29	6	638	6
52. Grey shale, broken	10	0	648	6
53. Grey shale	29	6	678	0
54. Fireclay	3	0	681	0
55. Grey shale	29	0	710	0
56. Grey shale and limestone	1	0	711	0
57. Grey shale	155	6	866	6
58. Grey shale, broken	10	6	877	0
59. Soft grey shale	11	6	888	6

At the time of my first visit the boring had reached a depth of 540 feet. The cores, which were all of small diameter, ranging down from 3 inches to $1\frac{3}{4}$ inches, had been laid out in order on shelves in a small core-shed. I broke up and examined samples taken by myself from the cores at intervals of about 10 feet, but fossils were disappointingly rare. Fragments of the trilobite *Phacops longicaudatus* ? (Murch.) were extracted from a core, $2\frac{1}{2}$ inches in diameter, that came from a depth of between 180 and 200 feet, and Mr. John Pringle afterwards found in the same sample a minute fragment of a graptolite, identified by Miss G. L. Elles as *Monograptus vomerinus* (Nich.) or its variety *M. vomerinus* (Nich.), var. *crenulatus*, Törnq. Traces of small brachiopods and trilobites, too imperfect for identification, were noticed at various depths. Additional samples of mudstone and limestone from the cores were brought to the Geological Survey Office in March, 1914, by a person interested, but as their depths were not known, they threw no further light on the Silurian sequence, though Mr. Pringle extracted from them some Pentamerid remains and a fragment of *Phacops*.

It is scarcely necessary to add that no part of the cores examined yielded a trace of a Carboniferous flora or fauna, and the record shows that no seams of coal were found from top to bottom. The solitary bed called "fireclay" (Item 54) can be dismissed as a band of sheared and slickensided mudstone. The wonder is that more were not recorded.

The interpretation of the section presents several difficulties. Item 1 is probably in part "made ground" or rubbish thrown down the slope from the old limestone workings, as it was said to be sandy and full of stones. In Item 4 can be recognized the mudstones with argillaceous limestone-nodules that overlie the Woolhope

Limestone in the openwork, as already described (p. 486). The thickness of the limestone itself, although amounting to 20 ft. 3 in. as cut by the boring, would, if measured at right angles to the bedding, be somewhat less, but could scarcely be reduced to 12 feet, the maximum space permissible in the openwork. It is possible, therefore, that the thickness at the outcrop has been reduced as the result of squeezing. The balls of limestone in Item 7 show that the conditions that preceded the deposition of crystalline limestone were similar to those which followed. The boring agrees with the surface exposures in showing the rapidity of the change from the grits and conglomerates of the Upper Llandovery to the shales, mudstones, and limestones of the Woolhope and Wenlock.

Item 8 forms the top of the Upper Llandovery Sandstone, and the white pebbles in the next item identify this bed with one of those exposed in the openwork. The cores, however, yielded no recognizable fossils.

But while there is no doubt that the upper beds of Items 8–19 represent the Upper Llandovery Sandstone, there is reason to believe that the lower of these beds are Longmyndian, and that a nucleus of Archæan rocks, directly underlying the Upper Llandovery, runs through the Corton ridge, probably from one end to the other. This suggestion is based on the following evidence.

Professor E. J. Garwood, during a visit at Easter, 1915, obtained from the site of the boring a sample of rock to which special interest attaches, on account of its strong resemblance to the conglomerates of the Bayston Group of the Longmyndian System. The rock is represented by part of a 3 in. core, which, with this diameter, must have come from the upper part of the boring. In the hand-specimen the rock is a pebbly tough grit, of a purple and green colour, composed of scattered subangular pebbles (up to $1\frac{3}{4}$ inches, the majority being about half an inch in length) of purplish-red quartzite approaching jasper in appearance, with others of white quartzite, set in a greenish-grey matrix of small quartz-grains, small greenish pebbles, and a greenish interstitial paste.

Under the microscope a slice of the rock (E. 11237)[1] shows that while many of the small quartz-grains are angular, others are rounded, and, as Dr. H. H. Thomas has suggested to me, appear to have been derived from the detrition of a quartz-porphyry. This is supported by the fact that one of the quartz-grains is partly surrounded by adherent glass. A few grains, about the size of the smaller quartz-grains, are of silicified banded rhyolite. The small green pebbles appear to be chloritic sediments; the interstitial paste seems to consist of chlorite and quartz, with limonitic iron oxide. The rock contains neither felspar nor calcareous matter.

A slice (E. 11236)[1] taken from one of the large pebbles of purplish-red quartzite conspicuous in the hand-specimen shows that the quartzite is thoroughly silicified, fine-grained, and contains many skeleton rhombohedra after some slightly ferruginous rhombohedral

[1] These numbers refer to the registered rock-slides in the collection at the Geological Survey Office, Jermyn Street, London.

carbonate. The purplish-red colour of this quartzite pebble is due to a slight film of red iron oxide that coats most of the grains.

Having these characters, the rock represented by this core agrees closely with some of the Longmyndian conglomerates, rather than with the softer and calcareous grits of the Upper Llandovery. The large diameter of the core and the fact that all the conglomerates met with in the borehole lie between the depths of 54 ft. 4 in. and 147 ft. 6 in. lead me to refer the specimen to some unknown position between these limits. Moreover, at 180–200 feet the core-diameter was only $2\frac{1}{2}$ inches. The record is, however, not sufficiently detailed to enable the base of the Llandovery to be located, though the mention of "green-grey sandstone" in Item 16 suggests Longmyndian. I conclude, therefore, that while the upper part of the 93 feet of conglomerates, etc., is Upper Llandovery, the lower part is Longmyndian. This is not at all improbable in view of the outcropping of conglomerates of this age at Pedwardine,[1] 6 miles to the north-east, and at Old Radnor,[2] 5 miles to the south-west; and it is not unlikely that the claret-coloured pebbles in the Llandovery grits of the Corton Quarry were derived from the neighbouring Longmyndian conglomerates.

At 147 ft. 6 in. the boring passed abruptly into a thick series of grey shales with a few thin grits and sandstones. Many of the beds are described as broken and veined with spar. That these grey shales are Silurian is proved by their yielding *Phacops longicaudatus ?* (Murch.) and *Monograptus crenulatus* or its near ally *M. vomerinus* at a depth of 180–200 feet. Mr. Philip Lake, to whom I am indebted for an examination of the trilobite fragments, considers that this species indicates a Wenlock horizon. Miss Elles thinks that the graptolite shows the beds to be low in the Wenlock Shales. It would seem, therefore, that the grey shales from $147\frac{1}{2}$ feet downward must be regarded as Wenlock Shales, and that the boring passed into them from the Longmyndian through a fault (Fig. 2). The 12 ft. limestone (Items 37–39) is probably a sporadic band and can hardly be the Woolhope Limestone, as it is underlain, not by the Upper Llandovery Sandstone, but by 535 feet of what are presumably more Wenlock Shales.

On this hypothesis a section through the borehole might be represented diagrammatically as in Fig. 2.

It is improbable that the dip of 55° seen in the exposures of the Upper Llandovery Sandstone close to the borehole prevails underground. The dip as seen in the cores below $147\frac{1}{2}$ feet seems to vary from 20° to 30°. From these rather meagre data the minimum displacement of the fault may be estimated at $888\frac{1}{2} - 29\frac{3}{4} = 858\frac{3}{4}$ feet, a throw that would carry down the Woolhope Limestone to some position below the bottom of the borehole. And as the Woolhope Limestone, Upper Llandovery, and supposed Longmyndian in the boring overlie Wenlock Shales, the fault must be an overthrust from the south. The thrust-plane, which would reach the

[1] A. H. Cox, "The Pedwardine Inlier": Quart. Journ. Geol. Soc., vol. lxviii, 1912, p. 364.

[2] C. Callaway, Quart. Journ. Geol. Soc., vol. lvi, p. 511, 1900.

surface along the foot of the ridge, accounts for the disappearance of the Woolhope Limestone outcrop in both directions.

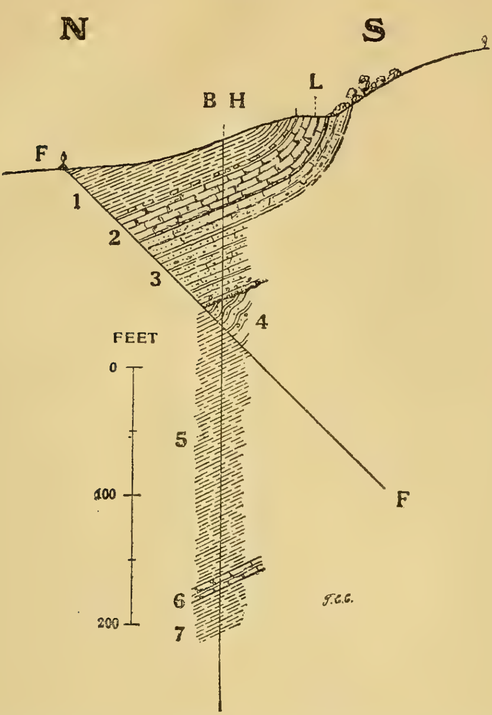


FIG. 2.—Vertical section, in a north and south plane, of the upper part of the Folly Farm Borehole, Presteign. L, lane; B H, borehole; F–F, overthrust fault; 1, 5, and 7, Wenlock Shales; 2, Woolhope Limestone and Shales; 3, Upper Llandovery Sandstone; 4, supposed Archæan (Longmyndian); 6, 12 ft. limestone-band.

The Folly Farm boring and drift are not the first nor the only recent attempts to find coal in the Silurian rocks of Presteign. Half a mile farther west, and 350 yards east of Caen Wood House, a shaft was begun in 1910, in the hope, as I was informed, of finding work for local labour by the setting up of a new industry. The debris from the shaft consists of light-blue and grey calcareous shales and mudstones. These yielded nothing but an *Orthis* and a few fragments of ill-preserved graptolites, doubtfully identified by Miss Elles as *Monograptus dubius* (Suess) or *M. colonus* (Barr.); but the evidence is perhaps scarcely sufficient to confirm the suspicion that the beds are Lower Ludlow.

The operations at the Folly Farm have not added so much to our knowledge of the local geology as might have been expected, but the boring shows the existence along the northern foot of the ridge of at least one important strike-fault, having the effect of thrusting older rocks from the south over newer. The fossils yielded by the mudstones in the borehole are few in number, but such as can be identified suggest a low Wenlock Shale horizon for the deeper beds. If the core believed by Professor Garwood to be Longmyndian is correctly identified, the Upper Llandovery Sandstones of the Corton ridge rest directly upon a nucleus of Pre-Cambrian rocks.

II.—Notes on new and imperfectly known Cretaceous Polyzoa.

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

(*Continued from the April Number, p. 148.*)

(PLATE XXXII.)

BESIDES the series of *Membraniporellæ* last described there are several other Cribrilinidæ which develop a secondary aperture in the same way, and the next four species are instances.

Cribrilina transita, sp. nov. (Pl. XXXII, Fig. 1.)

Zoarium unilaminate, adherent.

Zoœcia of medium size, average length ·7 to ·75 mm.; primarily they are of the usual type with low slightly arched side walls and arched front walls springing from the edges of the side walls, and traversed by radiating furrows pierced in their outer half by short and sometimes fairly broad slits, while at the inner ends there are preserved very irregularly remains of a system of one or two longitudinal rows of punctures; six rows of paired furrows with or without an unpaired one in the centre line seem to be the general standard; the aperture is roughly semicircular and its anterior lip bears four tubercles; in the secondary stage the side walls thicken and rise, filling up the spaces between the front walls, but only coalescing at occasional intervals; the secondary aperture is formed as usual from a denticle in the centre of the posterior lip of the primary aperture which is produced over this aperture as a flat wide bar, from the end of which (and from the sides of the primary aperture) there arises very steeply a thick ring leaving two slits on either side of the denticle and embracing the front part of the oœcium, on which the ring is flattened out somewhat angularly and bears two small pores in the angles.

Avicularia small beak-shaped, narrow, and elongated, with strong cross-bar close to the rounded end; a pair are generally placed on either side of the secondary aperture with their beaks directed inwards and generally more or less downwards and merging into the ring surrounding the aperture; others are scattered irregularly over the side walls.

Oœcia large, globose, with small apertures cut well back, very constant in occurrence.

This species is the only one in the group to show Cribriline perforation, and this fact and its tuberculated primary aperture suggest relationship to *Cribrilina furcifera*, Bryd.,[1] which itself provides a half-way stage between this type of secondary aperture and a simple aperture. It occurs quite rarely in the *Uintacrinus* band of Hants and Sussex.

[1] Geol. Mag., 1910, p. 391, Pl. XXX, Figs. 6–8.

Cribrilina T-formis, sp. nov. (Pl. XXXII, Figs. 2, 3.)

Zoarium unilaminate, adherent.

Zoœcia rather small, average length ·55 mm.; primarily they are of the usual type with very low side walls and rather strongly arched front walls traversed by radiating wholly imperforate furrows and a distinctly concave posterior lip to the aperture which is widely lenticular with a broad flat anterior lip; the furrows are very shallow and sometimes cannot be detected over a whole zoœcium; eight pairs seem to be the standard; in the secondary stage the side walls rise to a level slightly above the edges of the front walls and coalesce partly, but not wholly; a denticle forms on the posterior lip of the aperture and develops into a short rather narrow process stretching upwards at a low angle over the aperture and then giving off two branches, one on either side, at right angles to it, which curve downwards and form the posterior lip of the secondary aperture, whereby hiding the primary aperture; finally, the outer edge of the anterior lip of the primary aperture is produced forwards and raised slightly to form the thin anterior lip of the secondary aperture, which is in a highly inclined plane. When the light is from the foot of the zoœcium the anterior secondary lip, if formed, may be, and the primary anterior lip, if the secondary one has not been formed, is almost sure to be, invisible in shadow, and the zoœcium appears to end abruptly in a suspended T, which is very distinctive.

Oœcia scarce, rather flatly globose, rather large in proportion, with a wide aperture cut back rather sharply and squarely; sometimes the anterior lip of the secondary aperture rises and embraces the greater part of them.

Avicularia small, beak-shaped, with spatulate anterior ends when well developed, but accessory beak-shaped avicularia vary so much in a single zoœcium, according to their opportunities for development and their state of preservation, that no importance can be attached to variations in their appearance; they are scattered irregularly along the side walls, but tend to occur in pairs pointing towards the aperture from below and just touching the anterior lip.

This species occurs in the zone of *Offaster pilula* in Hants and Sussex and does not appear to survive that zone, nor in those counties to have any successor in the (restricted) zone of *A. quadratus*, but in the top beds of that zone in Suffolk it is succeeded by

Cribrilina Bramfordensis, sp. nov. (Pl. XXXII, Figs. 4, 5.)

This species is so closely allied to the preceding one that it is most easily described by enumerating the differences between them. *C. Bramfordensis* differs from *C. T-formis* in its greater size (average length ·8 mm.), its furrows deeply and squarely cut at the outer ends and more numerous (nine or ten pairs being a minimum, while the numerous small ones which can sometimes be detected round the anterior end, coupled with the increase in numbers which automatically accompanies any accidental increase in length, make it difficult to put any limit to the number that might be met with), the abundance of oœcia which are regularly overridden by the wide anterior lip of the secondary aperture, and the higher angle of rise of the anterior lip of the secondary aperture and the low angle of the plane of the secondary aperture when no oœcium is present. The sum of these differences is not over-convincing, but I think it is just sufficient to support a specific distinction which marks a substantial difference both in horizon and area.

The species occurs freely at the top of the (restricted) zone of *A. quadratus* at Bramford, Suffolk, and there are indications that it occurs rarely in the Weybourne and Trimingham Chalks.

Membraniporella subcastrum, sp. nov. (Pl. XXXII, Fig. 6.)

Zoarium unilaminate, adherent.

Zoœcia small, average length ·6 mm.; primarily they are of the usual type, with low, slightly arched side walls, arched front walls pierced by four or five pairs of short, narrow, radiating slits, and a semicircular aperture; in the secondary stage there is the usual formation of a secondary aperture from a denticle appearing on the posterior lip of the primary aperture and from the uprising of the latter's sides; the side walls rise and thicken as usual and fuse with one another and the margin of the secondary aperture and the oœcia so as to form a broad network, enclosing and raised above the front walls and encroaching on them so as to partly or even wholly cover up the slits, and featureless except for (1) the secondary aperture, which is more or less horseshoe-shaped with a strong tendency to a small denticle on the posterior lip, and the anterior lip formed mainly by the edge of the oœcium, which though inconspicuous is very regularly present; (2) the apertures on the side walls of small avicularia merged in the general mass and present fairly regularly at the lower corners of the secondary aperture and also irregularly elsewhere; the edges of the secondary aperture run a little way up the oœcium, but do not apparently unite across it.

Oœcia large in proportion, rather flatly globose, with aperture only slightly cut back.

This species is in nearly every respect an ill-defined ancestor of *Membraniporella castrum*, Bryd.,[1] the latter is readily distinguishable by its more numerous and conspicuous slits in the front wall, and its curious cavity in the posterior lip of the secondary aperture, which is indicated in the original figure, though not referred to in the original description, and is very useful for rapid diagnosis. A figure of an admirable specimen of *M. castrum* is given for comparison. *M. subcastrum* occurs rather scantily in the zone of *Marsupites* and the subzone of *E. scutatus* var. *depressus* in Sussex. Specimens are usually very obscure.

Membraniporella Gabina, sp. nov. (Pl. XXXII, Fig. 8.)

Zoarium unilaminate, adherent.

Zoœcia narrow, but rather long, average length ·75 mm.; the side walls are almost common, only faint traces of a separate origin being left, and are wide, especially at the ends, and the arched front wall appears to be laid on them and to overlap their edges considerably at

[1] Geol. Mag., 1909, p. 398, Pl. XXII, Figs. 4, 5.

the anterior end; the aperture is heel-shaped with a tiny denticle on the posterior lip, but it is often rendered more or less rectangular by the intrusion of the edge of the oœcium at the anterior end; along the edges of the front walls there are more or less paired openings of varying size, a long pair about the middle of the front wall being fairly regular in occurrence.

Oœcia large, globose, and very flat; I have only seen them with the shape of the aperture obscured or hidden by the margin of the zoœcial aperture.

Avicularia.—Small accessory avicularia with arrowhead-shaped apertures when well preserved occur very consistently in pairs beside or just above the zoœcial aperture and pointing towards it, while irregularly placed examples also occur.

This species occurs at the junction of the zones of *A. quadratus* and *B. mucronata* in the Isle of Wight and in Hants, but is very rare. It is obviously not a *Membraniporella* in any ordinary sense, but it appears at an horizon at which the Cribrilinidæ were unusually active in development, and it is so simple in structure and so closely analogous to many Cribrilinidæ, e.g. *Membraniporella tæniata*,[1] that I regard it as a highly aberrant *Membraniporella*.

Cribrilina repleta, nom. nov. (Pl. XXXII, Fig. 9.)

Syn. *Cribrilina suffulta*, Bryd., Geol. Mag., 1913, p. 437, Pl. XIV, Fig. 5 only.

I have come to the conclusion that my so-called "coarse form" of *Cribrilina suffulta* cannot, owing to its erect side walls almost fused together, be properly united with *Cribrilina suffulta*, whose zoœcia are typically pyriporiform and quite separate. The relationship between the two is, however, so very close that each is liable to display here and there a considerable measure of the distinguishing character of the other. I have figured an exceptionally well-preserved specimen which shows that the tubercles on the anterior lip are typically four in number, long and tapering, but very brittle. *C. repleta*, like *C. suffulta*, is nearly related to *Semiescharipora interrupta*, D'Orb., which is distinguished from them by an aperture longer than its width.

Cribrilina galanthis, nom. nov.

Syn. *Cribrilina Gregoryi*, Bryd., Geol. Mag., 1913, p. 437, Pl. XIV, Fig. 3 only.

I have also come to the conclusion that my so-called "coarse form" of *Cribrilina Gregoryi* should also be specifically distinguished. It differs from *C. Gregoryi* in the tuberculation of the anterior lip of the aperture, which is very indistinct, but I now think consists of traces of four tubercles only as in *C. repleta* (*supra*). It also differs in a strong tendency to squareness in the shape of the outer pair of the perforations in the front wall. Specimens occur occasionally in the lower part of the subzone of *E. scutatus* var. *depressus* which are very near *C. Gregoryi*, but are not definitely that species, and may perhaps be referred to this.

[1] Geol. Mag., 1917, p. 50, Pl. III, Figs. 3, 4.

EXPLANATION OF PLATE XXXII.

(All figures × 12 diams.)

FIG. 1. *Cribrilina transiens.* *Uintacrinus* band. Brighton. Broughton, Hants.
,, 2. ,, *T-formis.* Subzone of abundant *Offaster pilula.*
,, 3. ,, ,, Subzone of *E. scutatus* var. *depressus.* Rottingdean, Sussex.
,, 4, 5. *Cribrilina Bramfordensis.* Zone (restricted) of *A. quadratus.* Bramford, Suffolk.
,, 6. *Membraniporella subcastrum.* Subzone of *E. scutatus* var. *depressus.* Rottingdean.
,, 7. ,, *castrum.* Trimingham.
,, 8. ,, *Gabina.* Zone (restricted) of *A. quadratus.* Freshwater, Isle of Wight.
,, 9. *Cribrilina repleta.* Zone of *M. cor-anguinum.* Soberton, Hants.

III.—The Volcanic Eruption of 1913 on Ambrym Island, New Hebrides.

By Rev. M. Frater.

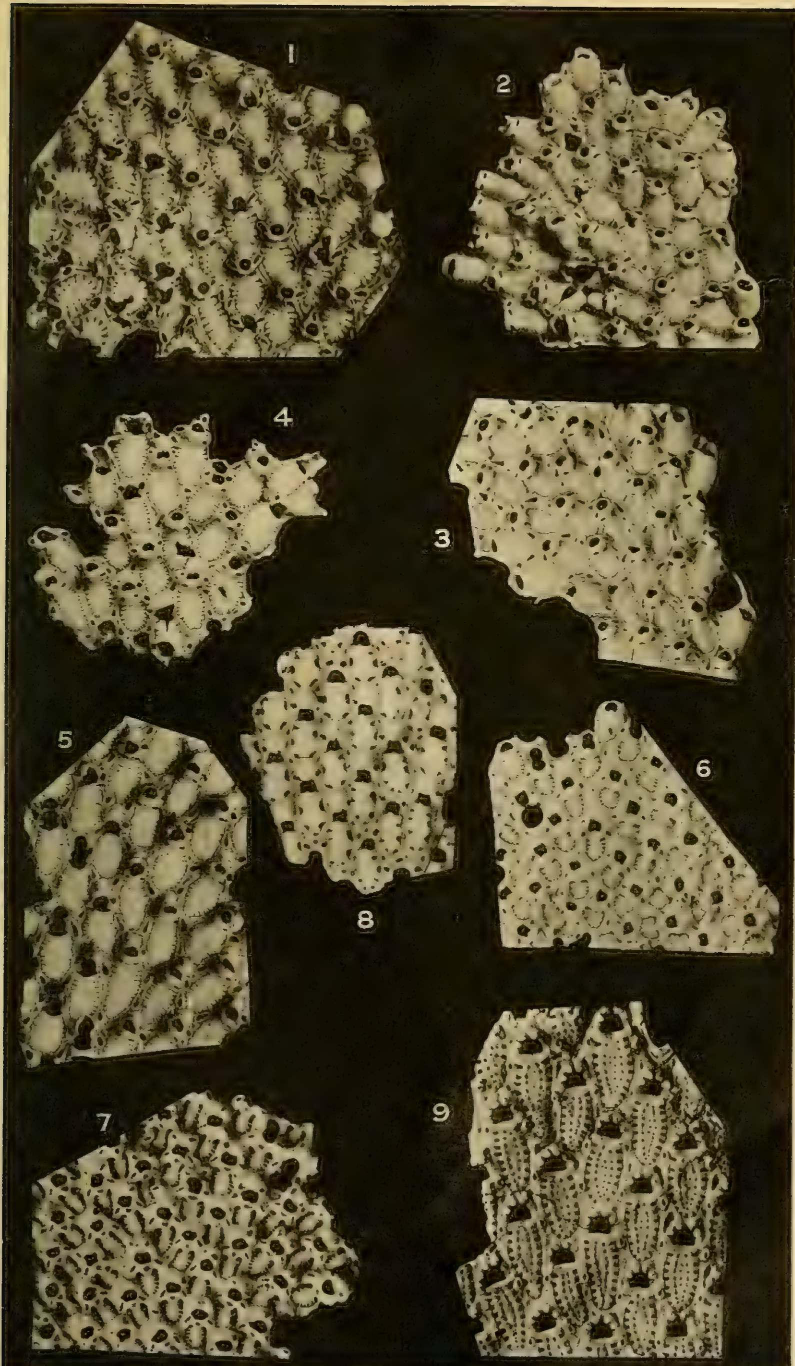
(Communicated by Professor J. W. Gregory, D.Sc., F.R.S.)[1]

THE New Hebrides group of islands was first fully made known to Europe by Captain Cook, who in the year 1774 spent forty-six days among them. Situated in the Southern Pacific, about 1,400 miles N.E. of Sydney, the total number of islands is nearly eighty, the largest of which has a coastline of 200 miles. The islands are mainly of volcanic origin and lie in a direction from S.S.E. to N.N.W. Volcanic action is almost exactly in the direction of the group of islands, and a line drawn from the volcano of Tanna in the south to the volcano of Tinakula in the north, a distance of 600 miles, would pass through the volcanoes of Lopevi, Ambrym, Ureparapara, and the boiling springs of Vanua Levu.

The line of volcanic activity which stretches across the Pacific Ocean runs through the New Hebrides Islands. Entering the Pacific from the direction of Java, the volcanic belt passes through Timor and extends to the large island of New Guinea, where it bifurcates. New Guinea seems to be a central focus from which the lines of fissure girding the Pacific radiate; one line goes northwards through Formosa and Japan, and the other southwards through the Solomon Islands, New Hebrides, New Zealand to Mount Erebus in the Antarctic Ocean.

[1] [The MS. of this paper was left with me by the Rev. M. Frater on his return to the New Hebrides for publication with some supplementary notes on the eruption after the arrival of his collection. The specimens have been kindly sent me by Admiral Parry, the Hydrographer of the Admiralty, and some account of them will be included in the Report on the Eruption to be published by his Department. This publication, however, may not be issued until the end of the War. Hence, it seems advisable to publish Mr. Frater's interesting account of the eruption without further delay. Mr. Frater acted as guide and interpreter to Commander Hancock during the resurvey of Ambrym after the eruption.—J. W. G.]

[The geological and petrological description of the Ambrym eruptions, by Professor J. W. Gregory, will appear in the December Number, with a Map of the Island.—EDIT. GEOL. MAG.]



P. M. Brydone, Photo. Bemrose & Sons Ltd., Collo.

Chalk Polyzoa.

The volcanoes in the New Hebrides group work in sympathetic agreement. Tanna volcano is the Stromboli of the Southern Seas. The eruptions of this volcano are still heard as in the days of Captain Cook. There is the "pillar of smoke" by day and the "pillar of fire" by night. It is the great lighthouse of the South Pacific. Like a revolving light it bursts out every three or four minutes with great brilliance. A few years ago the regular explosions suddenly ceased. The natives became alarmed; they had become accustomed to regard the volcano as the safety valve of the district, and they had sufficient knowledge of mechanics to understand that the closing of a safety valve is as dangerous in a volcano as in a steam-engine. In company with a crowd of natives, the resident missionary climbed to the edge of the crater and discovered that the walls had collapsed and choked the "fire". But no sooner had Tanna closed down than the volcano on Ambrym, 300 miles northwards, became more active. The eruptions from Ambrym, which had hitherto been spasmodic and irregular, now took place at regular intervals, glowing at night with an intermittent light resembling the flashing light of a lighthouse. Tanna remained quiescent for a few weeks, and then, with a convulsive roar, the imprisoned giant broke its bonds and awoke to life. The clock-work regularity of the Ambrym volcano ceased and the eruptions again became uncertain and spasmodic.

The same sympathetic relations which exist between Ambrym and Tanna also govern the workings of the Ambrym and Lopevi volcanoes. Situated on neighbouring islands, only 25 miles apart, their operations can be watched together. Violent activity in the one is almost invariably answered by outbursts in the other.

The destructive eruption of the Ambrym volcano with which this paper deals occurred in December, 1913. Named Mount Benbow, after one of the British warships which visited the group in the early days of European settlement, the lofty cone of the Ambrym volcano rises from the centre of an extensive ash plain, over 2,000 feet above sea-level. In the neighbourhood of Mount Benbow the ash plain is studded with a series of extinct craters, occasional puffs of steam being the only indication of the pent-up fire beneath. The ring-shaped crater wall which encloses the plain, like a wall of circumvallation, first led the survey party of the warship whose name the volcano bears to the now generally accepted conclusion that the ash plain is the basal wreck of a much loftier volcanic cone which was shattered by a volcanic eruption, and that the island of Ambrym, with its volcanic soil, now remains as a memorial to the destroyed volcano. For untold centuries Mount Benbow had been at work puffing out steam which at night reflected the glare of the molten lava bubbling within the crater walls. So accustomed had the natives become to its presence that the frequent outbursts occasioned no surprise. They cultivated the soil up to the edge of the ash plain at the base of the volcano. But all unknown to the natives, and to the French and English residents who had their homes on Ambrym, there stretched from east to west across the island a belt of volcanic fracture. On this fissure, hidden in many places, underneath a wealth of tropical vegetation, stood the Presbyterian Mission Station, with its commodious and well-appointed hospital. The site was one of the beauty spots of the New Hebrides Islands. The hills around were covered with the luxuriant vegetation of the tropics. Adorning the extensive clearing which encircled the mission station, were wide-spreading banyan-trees which had weathered the storms of centuries. Little did the promoters of the Medical Mission imagine that they were building over a slumbering volcano. Beyond the shape of the valley, which was undoubtedly crateriform, there was nothing to indicate that underneath the calm and luxuriance of external nature the forge of Vulcan was being set up. In the light of recent events there can be no doubt that the station was standing in the crater of an old volcano; but it showed no trace of any recent eruption, and among the natives no memory of any such catastrophe survived in the traditions of the district. Countless generations, too, must have elapsed in the populating of the crowded villages which thronged the district, and in Captain Cook's day the population was greater than it now is. The symbolism and system of sorcery which had grown around the native mythology was more intricate and subtle than that which flourished in most of the other islands, and pointed to a long succession of ages since fire had visited the district.

In December, 1913, the age-long sleep of the extinct volcanoes near Mount Benbow was broken, and from numerous thunder-throated vents the island was torn and rent with convulsive explosions. The eruption was heralded by a series of premonitory earthquake shocks. One of them, which occurred about a month before the outbreak, was the most severe in the memory of the natives. Immediately preceding the eruption, the shocks increased in frequency and severity until the solid earth reeled and tottered. The hospital buildings rocked like a ship at sea. The natives, in their manner of speech, said that Ambrym danced. Then there was seen to rise from the extinct craters a dense cloud which shot up into the air and spread out in all directions like a gigantic mushroom. Tremendous explosions followed each other in rapid succession. Blacker and larger grew the cloud until it lay like a London fog over the entire island. The erupting volcanoes followed the line of volcanic weakness. Beginning at the extinct craters in the centre of the island, the line maintained a westerly direction and every few miles a new volcano burst out. From the neighbouring island of Paama, where an unobstructed view of the eruption was obtained, its rise and progress could be watched. In one place which seemed to be a centre of disturbance, six volcanoes had formed within a short distance of each other. During the night the track of the red-hot lava could be seen like the trail of a serpent. Every outbreak brought the eruptions appreciably nearer the hospital until in the early morning, twelve hours after the first outbreak, the advancing flare could be seen behind the hills which encircled the Mission Station. At daybreak a dense black cloud was seen about a mile behind the station, but the hospital staff imagined that the bush had been set on fire by a lava stream. While they were watching it, a neighbouring trader who had two boys in the hospital arrived by motor-launch and reported that it was a volcano which had burst out. At the same instant, terrified natives from the inland villages arrived with the news that the earth had opened some distance up the valley and the molten lava had formed a lake of fire. They told of villages blown up, of villages surrounded by fire, of hairbreadth escapes from death. Most of the adults carried children. Large numbers of old people had been left behind to perish. Preparations were at once made for the removal of the patients. One of them, the wife of a missionary, had given birth to a child a few hours before, and she with her new-born son were the first to be rescued from the doomed hospital. Another lady, the wife of a planter, had her baby born when on the way to a place of safety. A motor-launch was filled with the more helpless patients and sent, under the charge of one of the assistants, to Malekula, an island 15 miles away. The launch had scarcely left the beach when the engine stopped; a valve had jammed. After watching for a little the medical superintendent rowed off in a small boat and, locating the trouble, banged the obstinate valve down with a hammer. As he was returning to the shore the doctor saw his wife and a number of hospital patients racing for their lives along the beach; the crisis had come one step nearer. At this moment the doctor went back to the station; he could see one side of a hill belching fire, not a quarter of a mile away; he set his teeth and made for the station and, when he had ascertained that the place was clear, made a race back to the boat on the beach, while the ground heaved and swayed beneath him. At the boat landing another problem confronted him; the sea was boiling hot, and the boat lay out a little from the beach. Fortunately, a box was found, and throwing it down at the edge of the water, the doctor sprang from it into the boat. The native crew pulled with might and main, but they had only gone a short distance when the earth reeled with a great thunder, and looking back the doctor saw the fragments of his house and hospital hurled into the air. A volcano had burst out in the middle of the hospital grounds, and from the place where the hospital stood a column of steam was shot up with such prodigious velocity that in less than a minute it had risen 20,000 feet above the level of the crater. At this elevation the particles of finely powdered rock were caught by the prevailing winds and carried great distances out to sea. A steamer running between Sydney and Fiji, several hundred miles away from the islands, had her decks covered with minute particles of volcanic dust. On the surrounding islands it rained ash and cinders, and vegetation was sheathed in a thick layer of sulphurous ash. Besides this a sticky mud rain fell, a mixture of condensed steam and ejected dust. The compressed steam rushing at lightning velocity through the main vent and the fissures in the sides of the crater formed a gigantic hydro-electrical machine and charged the atmosphere with electricity. Every few seconds there issued from the murky cloud, which hung like a pall over the island, flashes of vivid lightning. The French steamer *Pacifique* arrived on the scene four days after the eruption and, owing to the abundance of atmospheric electricity, could not get its wireless to work.

About two hours after the outbreak at the Mission Station, the eruption, still following the same line of weakness, made a further leap and reached its last stage. Out to sea, at a distance of about a mile from where the hospital stood, where there was a depth of 25 fathoms of water, a submarine volcano burst out and formed a crater cone 330 feet high, which was afterwards named "Sealark Hill" after the survey ship which was sent by the British Admiralty to make a survey of the island. The enormous quantities of "ejecta" which poured out of this volcano soon formed a connexion with Ambrym Island and added a considerable area to its extent. On the abatement of the volcano which swallowed the Mission Station, it was found that a lagoon, connected with the sea by a narrow channel, had formed in the crater, covering the entire mission compound. Over the place where the hospital stood there is a depth of 8 fathoms of water, and from the soundings made by H.M.S. *Sealark* it was ascertained that the lagoon forms a safe, land-locked hurricane harbour for ships of shallow draught, provided, of course, no other volcano bursts out. To most mariners, however, the shelter provided by the crater of a volcano from the violence of a hurricane will look like a choice between Scylla and Charybdis and, very probably, they will prefer to take the risk of the element they know best. The first time an attempt was made to enter the lagoon the mud around the edge was still boiling and steam was rising from all over the surface of the water. The sounding line was kept going and at 20 fathoms it dropped into the burning lava where the lead attachment was melted. While the sailors rested on their oars at the entrance of the lagoon a submarine explosion startled the occupants of the boat and quenched the desire for further exploration. It was no place for either men or angels to linger.

The configuration of the surrounding country has entirely changed. Only by the aid of instruments is it possible to locate the position of any particular place. Across the extensive valley which lay behind the hospital a range of hills 500 feet high had been raised. So complete was the destruction of the hospital and mission buildings that not even a match was left. Thousands of acres of fertile lands had been changed to barren wastes, forests were blasted, and large numbers of lives lost. All the old familiar landmarks on the shore had disappeared, and the hills in the background were covered with a thick layer of volcanic dust.

During the night when the hospital staff was watching the progress of the fire a lava-flow reached the sea about a quarter of a mile north-east of the hospital. Quite oblivious of their danger they crossed over to have a look at it. They saw the stream of molten metal,[1] like an incandescent avalanche, sweeping everything before it. Masses of rock and vegetation were borne along on its surface; it crashed through the big banyan-trees and teakwood giants; the trees were tossed into the air and rebounded like indiarubber balls. On the level ground near the coast the stream was travelling at the rate of four miles per hour, was 200 yards broad, and, on being traced after the surface of the lava had solidified, was found to have its

[1] This use of the term is consistent with that by miners and civil engineers.

source in a fissure eruption in the centre of the island. It is not easy to describe the kind of cauldron that was formed when this huge mass of molten metal reached the sea; it plunged into it with loud detonations; the red-hot lava was shivered like melted glass into millions of particles; gigantic blisters were formed, exploding like miniature volcanoes. The crackling noise was deafening, and to such a height was the column of steam and ash shot up that the spectators on a neighbouring island, twenty miles away, imagined that a new volcano had burst out on the sea-shore. The sky was darkened and, for miles around, the sea was covered with dead fish and debris of all sorts. Enormous quantities of pumice-stone floated on the water and covered the sea for miles.

By the time H.M.S. *Sealark* arrived in the islands the surface of the lava streams had solidified and it was possible for the Survey party to trace the flows from the shore to their sources in the interior of the island. A belt of fracture, marking the line of volcanic activity which runs through the island, was discovered, and on this line of weakness all the old and new volcanoes are placed. At the opposite end of the island, where volcanic action has become almost extinct, a considerable amount of vapour rises to the surface through fissures in the ground. From some of the fissures flows water hot enough for the natives to cook their yams. In their journeys across the island the natives use these places as camping-grounds where they can procure hot water without the labour of kindling fires. But of recent years, due possibly to the exhaustion of volcanic energy in the south-east part of Ambrym, the number, as well as the heat, of these hot springs is diminishing. Standing on an elevation near one of the volcanoes on the ash plain it is possible for the eye to follow the belt of fracture to the other end of the island, and then with an intervening channel of ten miles rises the lofty cone of the Lopevi volcano, indicating that it lay in the same line of weakness on the earth's crust.

During the visit of the Survey party, Mount Benbow was in violent eruption, and presented a beautiful sight. Every few minutes, and sometimes almost continuously, eruptions took place, and, with every explosion, gigantic clouds of dust and ash of crebriform shape were shot up to a great height. From the anchorage of H.M.S. *Sealark*, at the north end of the island, the officers measured the height of the column and found it to be 12,000 feet above the lip of the crater.

The mouth of the crater was one mile long and three-quarters of a mile broad. Standing on the lip of the crater it was possible to watch operations. With bellowing noise showers of hot stones were ejected, some of which fell uncomfortably near to members of the party who approached the danger zone. Blocks of rock, torn from the walls of the vent, were hurled into the air. The heavier rocks fell back into the crater, and the smaller and lighter, carried by the winds, were piled around the crater with more or less regularity, according to the direction of the prevailing wind. The fragmental materials thus accumulated were of all shapes and sizes, from the finest powdered stone to large blocks blown out of the crater walls. Volcanic bombs lay scattered around. They had been ejected in a pasty condition and readily took the impress of a coin. When broken the core was found to be porous, but in the passage through the air the outside had become rounded and smooth. From the lip of the crater the inner wall had a sloping dip of 1,000 feet to an extensive level plateau of what appeared to be boiling mud, from the centre of which rose another crater cone, which was partly obscured by vapour rising from the boiling mud as well as from the innumerable holes in its walls. From the inner crater came the explosions of steam and ash, but there was no possibility of looking into its interior.

Eight lava streams, of lengths varying from one to ten miles, flowed during the eruption. Some proceeded from volcanoes with crater cones, others from fissure eruptions which were marked by an absence of crater-shaped vents. The fissure eruptions ejected lava in larger quantities than the crater volcanoes, though the flow was not always from the central vent but from rents in the crater wall. So enormous were the floods of this molten metal that the lava stream pierced through the thick bush, forming tracks from 100 yards to three-quarters of a mile broad. Viewed from the sea these black cindery tracks, running inland through the dense vegetation, resembled railway cuttings, and the smell of the cooling slag tended still further to confirm the resemblance. Sometimes, the lava stream parted and enclosed timber-covered islets. The trees on these islets survived, like island stations on a railway line. The only trees which seemed to withstand the first onset of the avalanche were the giant she-oaks. The molten metal flowed round these forest kings and clasped them in its embrace. The trunks were slowly consumed and deep cylindrical holes were left, at the bottom of which could be seen the glowing red lava. These holes, ranging from 10 to 20 feet deep, assumed the shape of the tree-trunk, and on the sides of the encrusted lava could be seen the impress of the tree. The cooling of the lava must have been very rapid, as the bark of the trees on the edge of the stream, where there was little depth of fire, was not even burnt, but only scorched. Here and there on the lava streams were miniature cones formed by the escape of gas and lava from the liquid interior, and these cones, some of them 15 feet high, continued to spout molten lava long after the main stream had passed. Three months after the eruption, heated vapours were still issuing from these cones. The vapours, impregnated with iron and sulphur, were acting chemically on the rocks, and produced a wealth of variegated colours in which white, yellow, and red predominated. Underneath the surface of the lava streams there seemed to exist numerous vesicular cavities in which vapour was imprisoned. The tread of the feet produced a dull, hollow sound and reverberated like the noise of a drum. Many fissures and cracks in the stream were still spouting hot vapours, and in some of the cracks the rocks were glowing within a few feet of the surface.

The lava streams assumed a variety of structures due to the amount of aqueous vapour imprisoned. Some were slaggy and ropy with a smooth, glassy appearance, others of the scoriaceous type had


KUALA TEKAI
S. TEKAI
S. KECHAU
S. KENONG
S. JELAI
S. TEMBELING
KUALA LIPIS
S. LANNA
SIBAH
S. KRAMBIT
LUBOK SUKUM
TEMBELING
S. LIPIS
BENTA
S. CHIKA
PULAU GUAI
TANJONG LINDONG
PULAU PRIAS
S. TEH
110
JERANTUT
JERANSONG
KUALA JERANSONG
100
LEGEND
LUBOK PLANG
Road to Kuantan
Mesozoic Granite
BATU REDAP
KUALA KRAU
Gondwana Rocks
S. KRAU
90
PULAU CHENGAI
Boulder-in-Tuff Deposits
S. TEKAL
KUALA TEKAL
Tuffs & Lavas
Pahang Volcanic Series
KERDAU
S. PAHANG
80
Quartz-Porphyry & Granophyre
Railway
S. SEMANTAN
Raub Rocks
TEMERLOH
70
FROM GEMAS
MENGKARAK
GLOSSARY
S=Sungei = River
Pulau = Island
Kuala = Mouth
Lubok = Lynn
Tanjong = Headland
Geological Sketch Map of part of ULU PAHANG
4 2 0 4 8 12 16 20 Miles

a rough and cindery appearance. The resemblance between the slag heap of an ironwork and the natural lava is very striking. Indeed, to stand on a lava-flow with the eyes shut by the side of a steam blow-hole and with the smell of the molten metal in the nostrils, it does not require a great exercise of the imagination to transplant oneself from the volcanoes of the South Sea Islands to the ironworks in the Black Country of Great Britain. Travelling over the rugged, cindery flows was attended with difficulty and danger, and the jagged edges made progress slow.

A strange phenomenon was witnessed in one of the volcanoes. After belching molten metal for two weeks, its activity gradually subsided, and apparently, from out the same vent, torrents of ice-cold water began to flow. The same phenomenon was witnessed by an old French settler in a volcanic outburst twenty years previously. From the other volcanoes abundant streams of moderately cold water gushed out and occasioned no surprise, but ice-cold water and molten metal from the same fountain seemed strange and incongruous. The floods of ice-cold water followed the same course as the lava-flow, covering the lava with a thick layer of silt and ash. A good path was formed, rendering this lava track the easiest of all the streams to traverse. Following its course it is possible to trace the lava from the sea to its place of origin at the edge of the ash plain.

The phenomena presented by the Ambrym eruptions would seem to indicate that water played as important a part in fissure eruptions, where intermittent explosions of steam were absent, as in the violent eruptions from a crater cone where explosions of steam were present. Eight lava streams were formed during the eruption; some of them had their source in overflows of lava from crater vents amid paroxysmal explosions of steam, others welled out of the earth like a fountain without the formation of crater cones and without explosions of steam. But the presence of water was as marked in the one case as in the other. In the fissure eruption which took place near the village of Meltungan streams of lava literally gushed out of the fissures without intermittent explosions of steam. These fissures were characterized by an entire absence of volcanic cones and extruded a continuous stream of molten lava which flowed for miles until it reached the sea. The lavas from these flows were impregnated with as much aqueous vapour as the lavas from crater eruptions. From other islands, 15 to 20 miles away, these lava streams could be traced by the columns of steam which rose from the cooling metal.[1]

IV.—The Pahang Volcanic Series.

By E. S. Willbourn, B.A., Assistant Geologist, Federated Malay States.

(WITH A MAP, PLATE XXX.)

(*Concluded from the October Number, p. 462.*)

Description of Tuffs and Breccias of the Pahang Volcanic Series.

By far the greater part of the volcanic rocks of Malaya consists of fragmental deposits, which at first sight seem to be andesite-tuffs and andesite-breccias, for most of them contain abundant

[1] Dr. Gregory's description of the Ambrym eruptions will appear in the December Number.

fragments of andesitic lava. However, the majority also contain numerous fragments of quartz, some of which occur as isolated angular grains in the cement, others embedded in a very fine-grained siliceous rock, and sometimes showing rounded outlines and even bays, invaded by the siliceous aggregate. Tuffs which occur in certain localities, e.g. at Kuala Tekal, Tembeling, and Sibah near Kuala Lipis on the Pahang railway, contain the usual fragments of andesite-lava, with numerous fragments of quartz like those just described, and in addition fragments of rhyolite-lava or quartz-porphyry. It is probable that the great majority of the Pahang Volcanic Series of tuffs are formed of an admixture of andesitic, rhyolitic, and sedimentary material.

The first type to be described is an andesite-rhyolite-breccia[1] from the Benta–Kuantan road, at the 47th mile from Benta. There is no hand-specimen of this rock in the collection, but judging from the slide (Pl. XXIX,[2] Fig. 4) it is a dark-green rock, fairly fine-grained, with occasional red spots, made up of abundant fragments of andesite-lava and quartz, with occasional crystals of felspar and fragments of quartzite, set in a cement of quartz and calcite. In addition there are numerous pieces of altered rock, consisting of a fine-grained siliceous aggregate with large included quartz grains, and in one case enclosing a rectangular pseudomorph of magnetite, probably after felspar. Also there are some fragments of a highly altered rock, composed of a rather coarser quartz mosaic, with a little black iron-ore evenly distributed throughout the mass, and comparatively large irregular flakes of white mica.

The andesite-lava fragments are made up of felspar laths, usually untwinned and with a low extinction angle, set in a dark-green isotropic material which often includes large grains of magnetite. There is a greater quantity of glass in these lava fragments than in any of the andesite-lavas which have been noticed in situ. The felspar laths are bent, suggesting that the andesite fragments were hot plastic masses when they were detached from the parent body. Some of the lava fragments contain numerous cavities filled with a green chloritic mineral which is arranged in radiating fibres.

The quartz grains vary considerably in size and appearance, some being angular while others are rounded and have a corroded appearance. The quartzite fragments are stained red with hæmatite, and magnetite and hæmatite are widespread, both in the lava fragments and in the cement. The few felspar crystals which are contained in the tuff are usually broken, and in composition correspond to oligoclase-andesine.

Breccias similar to this occur outside Pahang in the south of Negri Sembilan *[3] and north of Johore *, but the rhyolite admixture cannot here be recognized definitely, and the numerous angular

[1] Described by Mr. Scrivenor in *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 43, No. 1851, pl. xi.

[2] Plate XXIX of rock-sections, also explanation, appeared with the earlier part of this paper in the October Number, facing p. 462.

[3] An asterisk marks the names of all those places in Malaya mentioned in the text which are outside the area shown on the accompanying Map, Plate XXX.

quartz grains may be shattered fragments from the volcanic neck. They are probably not a sandy admixture brought down by streams, for the fragmental volcanic rocks of this district are interstratified with a series of shales which were at one time calcareous, and from which sandy beds are typically absent.

A volcanic breccia was found occurring as boulders at Kuala Seli * in Selangor at the 13½ mile from Kuala Lumpur on the road to Ginting Bidei (not shown on map), and reference has already been made to the rock as perhaps revealing the age of the purple quartz-porphyry which is found as boulders on the Main Range between Kuala Lumpur and Bentong.

It is green in colour and is made up of angular fragments of the following rocks; quartz-porphyry something like that occurring in situ at Jeram Gading * and as boulders in this district and on Ginting Sempak *, quartzite, and small rounded pieces of a homogeneous fine-grained siliceous rock like those which occur in the felspathic grits that are so often associated with cherts. They may be of sedimentary origin or they may be devitrified lava. There are pseudomorphs of epidote and an opaque dust which have a wavy outline, and in form resemble the altered biotite crystals in the Ginting Sempak quartz-porphyry. In addition grains of quartz make up a considerable part of the rock, some of them angular, others having a rounded corroded appearance, and broken crystals of orthoclase and oligoclase-andesine felspar are also common. There is very little fine-grained material, but amongst it can be noticed some grains of secondary epidote.

About half a mile west of Tembeling a deposit of andesite-rhyolite-breccia is exposed in the railway-cutting which is probably near a volcanic neck, for it is a coarse-grained red rock, the fragments being often more than an inch across, and consisting of quartzite, limestone, lava (both andesite and rhyolite), and crystals of felspar, quartz, and occasionally augite, the cement being quartz-aggregate, calcite, and iron-ores.

The andesite-lava fragments are well preserved, and belong to the type with a ground-mass of very small microliths of felspar enclosing well-shaped augites partly altered to chlorite, calcite and magnetite, and biotite crystals which have been bleached and have sometimes been entirely obliterated by secondary iron-ores. The rhyolite fragments are much more altered, the ground-mass now consisting of a secondary aggregate of quartz in which round bodies which were originally spherulites can occasionally be distinguished under crossed nicols. The shape of the lava fragments is very irregular, but there is no sign of a rapidly cooled margin. These lava fragments are distinct in character from the deposits of boulders in tuff which will be described later, the principal point of difference being that they are not water-worn.

Another slightly different type exposed in the railway-cuttings near Kuala Tekal may be described as an andesite-rhyolite-tuff, and in the hand-specimen it is a dark-green rock containing small black lava fragments, and crystals of felspar, quartz, and biotite, varying up to ½ cm. across.

Under the microscope the lava fragments are seen to be of two varieties, one made up entirely of felspar laths with trachytic structure, the other being very fine-grained and containing spherulites. The felspar crystals also are of two varieties—oligoclase-andesine and orthoclase. There is a good deal of dark-green chloritic material spread throughout the rock.

A similar rock at Sibah near Kuala Lipis contains a good deal of secondary epidote and mica, some of which has been formed by the alteration of augite crystals. No augite is left unaltered, but the sharply defined octagonal outline of the pseudomorphs suggests that augite was the original mineral.

Andesite tuffs without considerable admixture of more acid material are rare, but a specimen of greenstone with abundant epidote collected on the Benta–Kuantan road near the main Gondwana outcrop east of the Pahang River is more basic than those hitherto described, and contains little, if any, rhyolite material. The fragments of andesite-lava contain small augites as granules interstitial to the felspar laths. Crystals of oligoclase-andesine and augite are common, and there are a few fragments of quartz which are penetrated by epidote, and which when viewed between crossed nicols look like fragments of granophyre in which the felspar has been replaced by epidote. Fragments of an altered shaly sedimentary rock occur, and so do occasional rounded grains of corundum. Magnetite is very abundant in this rock, most of it being secondary.

Besides the above types, consisting in the main of fragments with very little fine-grained matrix, there is the compact type of tuff, in which the bulk of the rock is made up of a very fine-grained material, now of a siliceous nature.

Such deposits can only be determined as volcanic when a considerable number of the larger fragments are of felspar or, as only rarely happens, when fragments of lava can be recognized; in fact, there is an insensible gradation into a sedimentary grit. Probably many rhyolite tuffs are of this nature, and cannot be distinguished from felspathic grits. Then, again, other rocks very much resemble rhyolite tuffs, but they cannot be distinguished from partly altered rhyolite-lava flows unless some field evidence is forthcoming.

Deposits of Boulders in Tuff.

A most remarkable deposit is found in Pahang associated with tuffs and breccias similar to those already described. It consists of rounded masses of lava, tuff, acid intrusive rocks, or sedimentary rocks embedded in a fragmental matrix, the masses being very different from bombs and lapilli which are usually associated with tuffs. In several of the known exposures the boulder-in-tuff deposit passes into the usual tuff without boulders or pebbles.

Their characteristics are summed up as follows:—

1. They vary in size from a pea to over a yard across (at Kuala Tekal).

2. They are water-worn, show no sign of vesicular structure, and have not a glassy margin.

3. They are sometimes arranged in definite strata where they occur as pebbles of small size, e.g. at Tanjong Lindong.

4. In composition they coincide with the Pahang Volcanic Series rocks found in situ, including andesite-lava, rhyolite-lava, andesite-rhyolite tuffs and breccias, quartz-porphyry, and granophyre. No dolerite boulders have yet been found in these deposits. In addition to these volcanic rocks, one boulder of reticulating quartz veins was found in the Kuala Tekal section, and at Batu Redap many of the pebbles consist of a rock which should be described as a slightly felspathic grit—though it may be a fine-grained rhyolite-tuff. There is no distinction between the mode of occurrence of the sedimentary rock and the vein-quartz as boulders in the tuff, and the much more numerous boulders of igneous rocks.

The table on p. 508 gives the different localities in which the boulder deposits are found and the nature of the boulders.

Some of the boulders in tuff at Pulau Guai (see Map, Plate XXX) are of a rhyolite with numerous dark angular shale-inclusions, some of which contain crystals of chiastolite. This rock contains a good deal of calcite mixed with it.

It is very like a rhyolite-lava with shale-inclusions which occurs in situ at Pulau Chengai. Unfortunately, in the field the Pulau Chengai rock was mistaken for a conglomerate belonging to the Gondwana series, and certain other exposures near here which were named as coarse-grained quartzites may be really this same rhyolite-lava with inclusions of shale, so nothing can be said with certainty as to whether the boulder deposits of Pulau Chengai occur near the boundary of the Gondwanas and Raubs. This cannot be taken as evidence, but it will be seen from the third column of the following table that there is evidence to show that the boulder deposits occur always at a boundary of an outcrop of Gondwana rocks with Raub rocks.

The tentative theory as to their origin,[1] put forward by Mr. Scrivenor, the Government Geologist, was "that they were derived from already consolidated sheets of lava and ash, and masses of igneous rock consolidated below the surface, and that they became rounded by attrition in some way we cannot explain before they were shot up into the sea and fell back on ash being deposited on the sea-bottom".

Owing to the infrequency of exposures the field relationships of the deposit are very little known, but, in the nine districts where the deposit has been examined, the small amount of evidence that can be collected indicates that the deposit lies at the junction of Raub and Gondwana rocks. It is probable that there was an important unconformity between the Raub Series and the deposition of the Gondwana rocks, and evidence for this is afforded by the occurrence of pebbles of veined chert and Pahang Volcanic Series rocks in the Gondwana conglomerates. It seems likely that the pebbles were derived from cherts and Pahang Volcanic Series rocks of Raub age, and the fact that sufficient time elapsed after the formation of the

[1] *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 47.

No. Locality.	Nature of Boulders.	Remarks as to Associated Rocks, etc.
1. Near Kuala Tekai, Tembeling River.	Tuffs andesite. Quartz-porphyry (?).	Country rock is Gondwana quartzites, etc., yet the boulder deposits contain much calcite.
2. Pulau Guai (Pahang River).	Rhyolite - andesite - tuff. Rhyolite-lava, andesite - lava. Quartz - porphyry and porphyrite.	Up-stream from here the nearest sedimentary rock in situ is Gondwana quartzite $1\frac{1}{2}$ miles away.
3. $114\frac{1}{2}$ mile, railway.	Much weathered, no specimens collected.	Quartzite near 115th mile. Exposures too much weathered at and near $114\frac{1}{2}$ mile to say whether Raubs or Gondwanas.
4. Tanjong Lindong to Pulau Prias (Pahang River).	Rhyolite, andesite, and perhaps quartz-porphyry.	An outcrop of Gondwana quartzite occurs near Bulau Prias.
5. 105th mile, railway.	Andesite, trachyte, rhyolite or quartz-porphyry, granophyre.	At boundary of Gondwanas and Raubs. Granophyre is in situ in Raub Series rocks within 3 miles of this place.
6. Kuala Jeransong to Lubok Plang (Pahang River).	Rhyolite and perhaps quartz-porphyry.	Chert is interstratified with the tuffs at Lubok Plang, also rhyolite-lava flows. The surrounding country rocks are Raubs.
7. Batu Redap (Pahang River).	Felspathic grits, perhaps volcanic.	The railway is within a mile or so and core-boulders of quartzite are lying on limestone, so there may be a junction of Gondwanas and Raubs near here.
8. Pulau Chengai (Chengali), Pahang River.	Rhyolite and perhaps rhyolite-tuff.	Probably near boundary of Gondwana and Raub rocks.
9. Kuala Tekal, 87th mile, railway.	Rhyolite quartz-porphyry, and porphyrite.	Cuttings too much weathered to determine whether the sedimentary rocks belong to the Raub Series or whether they are Gondwanas.

Raub cherts for them to undergo veining before being eroded shows that the unconformity was an important one. This theory was explained in full in 1911 by Mr. Scrivenor,[1] but at that time it was thought that the chert beds formed a single separate series between the Raub and Gondwana rocks, whereas it is now known that many of the chert beds of the Peninsula are interstratified with Gondwana quartzites.

If the deposits of boulders and pebbles in tuff occur at the boundary of Raub and Gondwana rocks, it is fairly clear that they were formed during the period between them, i.e. in the period of terrestrial conditions.

Mr. Scrivenor said in 1911, that they bear resemblance to the "ashy conglomerate" of the Mendips, described by Professor S. H. Reynolds,[2] but added that after examining Mr. Scrivenor's photograph of the Pulau Guai beds (plate ix, Ulu Pahang memoir) Professor Reynolds thought that the two deposits do not agree. The bedding observed in the Pahang deposits is a point of difference from the Mendip "ashy conglomerate". Professor Reynolds gives four possibilities as to the nature and origin of the Mendip deposit, and one of them, slightly amended, is now suggested as accounting for the Pahang deposit.

The deposit of boulders and pebbles in tuff was laid down during the latter part of the unconformity which followed the Raub period, and during the subsidence when the Gondwana rocks were formed. The line from Kuala Tekai on the River Tembeling to Kuala Tekal on the River Pahang marks the position of the coastline during a pause in the depression, in which beach deposits were formed in sheltered parts of the coastline, and were mixed with volcanic ash which all this time was being deposited on the sea-floor by active volcanoes. Sufficient time must have elapsed between the beginning of the terrestrial conditions and the end of the period of formation of the beach-deposit to allow for the denudation of the considerable thickness of sedimentary rocks which must have covered the quartz-porphyry, granophyre, and other intrusions, for boulders of these intrusive rocks are common in the beach-deposit.

This theory explains the heterogeneous nature of the boulders and pebbles and their well-rounded appearance. It also explains the bedded nature of the deposit and its association at Lubok Plang with a band of chert, for it has been suggested before that chert can be formed in shallow water if the growth of Radiolaria is favoured by abundant silicates being supplied to the sea-water[3] by gases from

[1] *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 56.

[2] Quart. Journ. Geol. Soc., vol. lxiii, p. 227.

[3] J. B. Scrivenor, "Radiolarian-bearing Rocks in the East Indies": Geol. Mag., Dec. V, Vol. IX, No. VI, June, 1912, pp. 241–8. Mr. Scrivenor discusses the origin of the Peninsula chert, and points out that in Kedah the chert is not associated with volcanic rocks. He suggests that 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.

volcanic effusions.[1] The absence of any great quantity of sedimentary material can readily be understood, as also the fact that the boulder-in-tuff deposit often passes into a tuff devoid of pebbly material.

The theory that the boulders were deposited in water near a shore-line helps to explain a peculiar circumstance noticed with regard to the tuffs near Pulau Guai. There is a series ef exposures of granophyre over a distance of 4 miles to the north of Pulau Guai, one occurring only about a hundred yards up-stream from the first boulder deposit, and all the tuffs between Pulau Guai and Kuala Tembeling contain fragments of granophyre, whilst of the many specimens of tuffs examined from Pulau Guai only one contained what might be regarded as a fragment of granophyre. At the 102nd mile on the railway there is an intrusion of granophyre, while 3 miles further north is a boulder deposit in tuff. One of the boulders consists of granophyre, and fragments of granophyre occur in the tuff at the 105th mile and in tuffs between there and the intrusion.

The granophyre was exposed by the action of denudation during the period of unconformity, and fragments of it were carried down by stream action and deposited with tuffs which were being formed by active volcanoes at the time. Evidently the shore-line moved from west to east or a little north of west to a little south of east, and this explains the change from tuffs with granophyre fragments to tuffs without granophyre fragments when going down-stream at Pulau Guai, for as soon as the outcrop of granophyre became submerged below low-tide mark it would no longer be subject to denudation.

It was hoped to include in this paper a comparison of the Pahang Volcanic Series with the older volcanic rocks of the Malay Archipelago, as described in various Dutch and German publications, but the process of translation has proved so laborious and slow that it has not been possible to compare them with the volcanic rocks of any other districts but the Goemaigebergte of South Sumatra, which are described by Dr. Emil Gutzwiller in *Mijnwezen*, 1912, *Verhandelingen*.

Comparison of the Pahang Volcanic Series with the Permo-Carboniferous Volcanic Rocks of the Goemaigebergte, South Sumatra.

There are no older acid intrusive rocks in Sumatra which correspond to the quartz-porphyries and granophyres of Pahang, nor are there any rhyolitic lavas or trachytes.

Dolerites.

Those rocks of the Goemaigebergte which typically have an ophitic structure are divided by Dr. Emil Gutzwiller into two groups, the diabase-porphyrites and the diabases; the former group containing no olivine or diallage, while the second group usually contain one or other of them.

Very few specimens of dolerite of the period of the Pahang Volcanic Series have been collected in Pahang, so a detailed comparison

[1] E. E. L. Dixon, Quart. Journ. Geol. Soc., vol. lxvii, pp. 511–31, 1911.

of the specimens in the two countries would be without value, but one difference is sufficiently clear, namely that the felspar of the Pahang Volcanic Series dolerites is very much more acid in character, varying, in the five or six specimens examined, from oligoclase with an extinction angle of 12° to andesine. As already mentioned in the detailed description of the Pahang Volcanic Series dolerites, one of them contains quartz which is probably original. The alteration of the augite in both series results either in the formation of chlorite or of an amphibole. None of the dolerites collected from the Pahang Volcanic Series contain either diallage or olivine.

Andesites.

Dr. Emil Gutzwiller follows the custom of the Continental petrologists in using the name *porphyrite* for the older andesitic lavas.

Judging by the descriptions of the ten Goemaigebergte porphyrites given in *Mijnwezen*, 1912, the most obvious difference is in colour, for none of the porphyrites of South Sumatra have the red-brown colour which is so typical of many of the Pahang Volcanic Series andesites. A more important difference is in the composition of the felspar, for only two specimens out of the ten contain oligoclase-andesine, the remainder having felspars varying from andesine-labradorite (three specimens), through labradorite (two specimens), to bytownite (two specimens) and anorthite (one specimen), whereas the felspar of the Pahang Volcanic Series andesites on the other hand is never more basic than andesine.

The mode of alteration of the felspars in both the Pahang Volcanic Series and the Sumatran andesites is occasionally the same, then resulting in both cases in the formation of chlorite, but usually there is a considerable difference in the products of alteration of the two series, which is to be expected after considering that, apart from occasional specimens, the composition of the felspars in the two series is so widely different. In many of the Pahang Volcanic Series rocks the alteration product is a brown, opaque, extremely fine-grained material, which is probably kaolin, often associated with tiny flakes of secondary mica, not a common mode of alteration for the felspar of the Sumatran rocks. On the other hand, the felspar of the Sumatran rocks is often altered with the separation of epidote and calcite (saussurite). The oligoclase-andesine felspar of one of the Tembeling andesites contains a good deal of epidote, but in most of the Pahang Volcanic Series rocks the epidote which they contain has not been formed from the felspar. These rocks usually contain calcite, sometimes formed by alteration of the felspar, but often simply added to the rock by infiltration from neighbouring calcareous sediments.

The porphyrites of South Sumatra are divided petrologically into two groups, the labradorite-porphyrites and the augite-porphyrites, the first group containing no phenocrysts of pyroxene, but in some cases (Nos. 7, 8, and 9 Gloegoer) chlorite aggregates occur which are undoubtedly secondary after amphibole or pyroxene. In some of these, augite grains occur unaltered in the groundmass. A similar division of the Pahang Volcanic Series andesites into those with and those without augite could be made, but, as already mentioned, it is quite possible that all the andesites originally contained augite, which in some cases has been weathered to chlorite. The shape of the chlorite aggregates in some of the lavas confirms this idea, but in others chlorite occurs only as irregular areas in the groundmass, and there is no confirmatory evidence as to its origin.

Titanite is an alteration product common in the Sumatran rocks, whereas it was seen in only one of andesites of Pahang; some of the Sumatran augite-porphyrites are uralitized, and titanite occurs as a secondary product formed during this change. Another point of difference is that some of the Pahang Volcanic Series andesites contain olivine, whereas none occurs in the Sumatran porphyrites.

Apart from the differences mentioned above, the andesites of the two series bear a certain resemblance one to the other. Both are practically always holocrystalline with plagioclase felspar making up the greater part of the rocks as phenocrysts and groundmass, the latter containing little or no glassy base. Apatite is widespread in small quantities in all the Pahang Volcanic Series and Sumatran andesites, and a colourless augite with its alteration products are also widely distributed. Rhombic pyroxene is always absent.

Serpentine.

Serpentine and peridotites are found in many of the islands of the Dutch East Indies, including Java, Borneo, the Moluccas, and the west coast of Sumatra. Dr. Verbeek writes a description of all these occurrences in *Mijnwezen, Wetenschappelijk gedeelte*, 1905, and from this it appears that the serpentine in all these places was derived from olivine. Most of the serpentine outcrops in the Peninsula show no traces of the original rock, but occasionally, as in Negri Sembilan, remnants of amphibole suggest that the serpentine owes its origin to that mineral. An outcrop in the Perak River, however, resembles serpentine of the islands of the Archipelago in containing remnants of olivine.

Tuffs and Breccias.

They differ in much the same way as do the Sumatran lavas from the Pahang Volcanic Series lavas. The andesitic constituents are similar, except in the composition of the felspars, but no simultaneous effusion of rhyolite material took place in Sumatra, and so the Sumatran fragmental rocks differ from those of Malaya in that the tuffs are of an unmixed andesitic composition. The same difference applies to the breccias of the two areas. There is nothing similar to the remarkable deposits of boulders in tuff in the Sumatran area.

The age of the Sumatran volcanic rocks is given by Verbeek[1] as youngest Palæozoic, while Volz[2] gives them a pre-Triassic

[1] R. D. M. Verbeek, "Top. En. geol. beschrijving van een gedeelte van Sumatra's West Kust": Batavia Landsdrukkerij, 1883, p. 270.

[2] W. Volz, "Zur Geologie von Sumatra": Geol. und paläontol. Abhandlungen herausgegeben von E. Koken, Neue Folge, Bd. vi, Hft. ii, pp. 87 ff., Jena, 1904.

age, and on account of this Dr. Aug. Tobler, in his description of the volcanic rocks of South Sumatra in *Mijnwezen*, 1912, assigns them to the Permo-Carboniferous period. Thus, in age the Sumatran and Malayan volcanic rocks correspond, for the latter are extensively interstratified with Raub rocks, and certain fossils from limestone beds belonging to the Raub Series give it a Permo-Carboniferous age.

Volz says that the volcanic rocks of South Sumatra do not persist so late as the Triassic period, and this is a point of difference from the Malayan rocks, for the latter were being deposited during and probably later than the period of formation of the Lower Gondwana beds of Pahang, which are correlated with the uppermost Trias.

The Tertiary volcanic rocks of the Goemaigebergte seem, from Dr. Gutzwiller's descriptions, to contain no epidote, and this agrees with the rocks of the Malay Peninsula, where rocks younger than the Mesozoic granite contain no epidote. It will be remembered that some specimens of the dark-purple quartz-porphyry of Selangor contain epidote, and that this is taken as evidence of the pre-Granitic age of the intrusion.

Conclusions.

It is not possible to define the limits of the volcanic period with any certainty. The majority of the tuffs and lavas are interstratified with Raub shales, and fossil evidence proves that some of them are of Permian age. The field evidence suggests that the Raub shales are contemporaneous with the Raub limestones, and the latter contain fossils of Upper Carboniferous Limestone (*Visean* age), but no volcanic rocks have yet been seen that were underlain and overlain by Raub limestones. A boulder-in-tuff deposit was seen in contact with a vertical face of limestone in the river bank a few hundred yards down-stream from Lubok Plang, but according to the theory that the boulders are a beach-deposit it is certain that the deposit is lying unconformably against the limestone. So we have proof that there was volcanic activity during the Permian period (late Raub), and there is no proof that it started so early as the Carboniferous period.

It is possible that volcanic activity continued during the period of dry land which prevailed through the greater part of the Triassic and perhaps during a part of the Permian period, and we know that tuffs were being deposited at the coming on of the Gondwana shallow-water conditions, when the beach-deposit was formed.

Tuffs and lavas were extruded during the deposition of the earliest Gondwana rocks in the north and south zone now marked by the Pahang and Tembeling Rivers and probably also further to the east, though this last point has not been investigated. No cases of Pahang Volcanic Series intrusions penetrating Gondwana rocks have been noticed, though there are several doubtful cases; for instance, the granophyre north of Pulau Guai and the quartz-porphyry at Jeram Gading*. However, if the beach-deposit of boulders in tuff was formed immediately before the earliest Gondwana rocks of the locality it is clear that the granophyre was intruded and laid bare before this date, for granophyre boulders are included in the deposit.

Rhyolite-lavas were extruded during the Raub period, and apparently eruptions of acid rocks and andesites occurred alternately. There is no evidence that rhyolites were extruded as lavas later than the Raub period, but eruptions of andesitic composition took place during the formation of both the Raub and Gondwana rocks, and as the eruptions were in full activity during the formation of the earliest Gondwana beds it is possible that they persisted through the period of dry land.

All the Raub volcanic rocks that have been examined were evidently deposited under the sea, and such was the case too with the Gondwana volcanic rocks, though in the latter case it is quite probable that for some time the volcanic vents continued to be above sea-level. Radiolarian cherts are associated with Pahang Volcanic Series rocks at Lubok Plang and on the Main Range in Lower Selangor*, and it is possible that the silica in the sea-water necessary for the building up of Radiolarian tests was supplied by pneumatolytic emanations from these eruptions. However, no proof of extensive albitization of the Pahang Volcanic Series rocks is available, and this is a serious drawback to the theory that the two rocks are related in origin.

The only intrusion of dolerite that was seen on the Pahang Railway was in a weathered railway cutting near the boundary of Gondwanas and Raubs, and it was uncertain whether or not it penetrated Gondwana rocks. There is no proof whether the dolerite is of Raub or Gondwana age. The absence of dolerite boulders from the beach-deposit can be explained by the scarcity of the dolerite outcrops, and does not prove anything about the age of the intrusions.

NOTICES OF MEMOIRS.

I.—Swiney Lectures on Geology.[1]

A course of twelve lectures[2] on "The Mineral Resources of the British Empire" will be delivered by Dr. John S. Flett, F.R.S., at the Royal Society of Arts, 18 and 19 John Street, Adelphi, W.C.

Syllabus.

Lecture I. Tuesday, November 13. Introductory.—The mineral industries in peace and war. Relation of mineral production to Colonial development. Distribution of minerals of economic value in the British Empire. Trade between Britain and Colonies in minerals, metals, etc., in normal times. Effect of war on mineral production and distribution in the Empire. Statistics of British Imperial production. Resources of the Empire in minerals.

[1] With the sanction of the Trustees of the British Museum (Natural History).

[2] The lectures will be given on Tuesdays, Thursdays, and Fridays at 5.30 p.m., beginning Tuesday, November 13, and ending Friday, December 7, 1917. To be illustrated by lantern slides. Admission free.

II. Thursday, November 15. Gold.—World's production of gold at different dates. History of gold-mining in Great Britain. Gold-mining in early times in India, Africa, etc. Discovery of gold in Australia: history and present condition of gold-mining in Australian States. South African goldfields: Transvaal, Rhodesia, etc. Gold-mining in India, Canada, British Guiana, New Zealand, etc.

III. Friday, November 16. Silver, Platinum.—Sources of silver and nature of silver ores. Extraction of silver from lead ores. Silver production of Great Britain. Canadian silver-mines and the history of their development. Australasian silver-mines, especially Broken Hill. Platinum deposits of British Columbia.

IV. Tuesday, November 20. Iron.—Occurrence of iron ores and their origin. Production of iron in Britain and the Empire. Iron-ore deposits of Great Britain. British imports of iron ore and their sources. Iron-ore deposits of Canada and of the Australian States. Iron-ore deposits of South Africa.

V. Thursday, November 22. Coal.—Origin of coal and nature of the different varieties. Properties and utilization of coal. Coal-production of the Empire. Exports and imports of coal. British coal-fields and their resources.

VI. Friday, November 23. Coal (*continued*).—Coal-fields of Canada: their production and reserves. Coal-fields of India. Coal-fields of South Africa, Rhodesia, Nigeria. The coal deposits of the Australian States.

VII. Tuesday, November 27. Oil.—Sources of mineral oil: their method of origin and mode of occurrence. History of oil industry and world's production of oil. Oil shales of Scotland, Australia, and Canada: their treatment and their products.

VIII. Thursday, November 29. Oil (*continued*).—Oil and pitch in Trinidad. Oil and gas wells of Canada. Oil-fields of Egypt, Burmah, New Zealand, Persia. History of mineral oil and geology of the oil-fields.

IX. Friday, November 30. Salt, Phosphates, Sulphur, etc.—Deposits of rock salt in Britain, Canada, India, etc. Mineral phosphates in British possessions. Sulphur and pyrites: their distribution and uses. Asbestos mines of Canada, Africa, etc. Graphite of Ceylon. Nickel and cobalt in Canada.

X. Tuesday, December 4. Copper, Tin, Tungsten, etc.—Copper and tin mining in Britain. Copper production in Canada, Africa, New Zealand. Tin-mining in the Malay States. Tungsten: the sources of supply in the British Empire. Molybdenum.

XI. Thursday, December 6. Lead, Zinc, Manganese, etc.—British lead-mining, past and present. Sources of lead and zinc for British industries. Zinc-lead ores of Australasia. Canadian lead and zinc deposits. Manganese ores of India. Antimony.

XII. Friday, December 7. Diamonds and other Precious Stones.—Indian diamond production. The diamond fields of South Africa and South-West Africa: their geology and history. Australian diamonds. British Guiana. The Burman ruby deposits. Precious stones of Ceylon. Queensland opals and sapphires.

II.—A Paleocene Bat. By W. D. Matthew. Bull. Amer. Mus. Nat. Hist., vol. xxxvii, pp. 569–71, September, 1917.

BATS with well-developed wings are already known from the Upper Eocene of Europe. A highly specialized skull of a bat has now been found in the still older Basal Eocene (Wasatch formation) of Colorado, U.S.A. According to Dr. Matthew, this specimen represents a new genus and species of the family Phyllostomatidæ, which still exists in tropical America. It has an unusually slender snout and a comparatively small canine tooth.

III.—Huesos anormales de Llama y de Condor. By Cayetano Martinoli. Physis (Buenos Aires), vol. iii, pp. 69–74, 1917.

PALÆONTOLOGISTS have long been interested in rare cases of three-toed horses, which recall the condition of the foot in the Miocene and Pliocene Equidæ. Martinoli now describes and figures an analogous case of polydactyly in a llama (*Auchenia lama*). As shown by his figure, the abnormal metacarpus consists of four well-defined bones fused together, and all probably bore phalanges.

IV.—The Albertella Fauna located in the Middle Cambrian of British Columbia and Alberta. By Lancaster D. Burling. *American Journ. Science*, vol. xlii, pp. 469–72, 1916.

THE Albertella fauna has hitherto been regarded as Lower Cambrian, but certain new facts of stratigraphy are mentioned in this paper to prove its Middle Cambrian age. Text-figures are given of *Albertella bosworthi*, Walcott (British Columbia), and *A. helena*, Walcott (Montana and British Columbia).

REVIEWS.

I.—Fossil Plants; a Text-book for Students of Botany and Geology. By A. C. Seward, M.A., F.R.S. Vol. III: Pteridospermæ, Cycadofilices, Cordaitales, Cycadophyta. 8vo; pp. xviii, 656, with frontispiece and 253 text-figures. Cambridge University Press, 1917. Price 18*s.* net.

PROFESSOR SEWARD'S book is a continuation of his systematic account of fossil plants, taken up from the end of vol. ii, which appeared in 1910. The author was so rash as to make certain statements in his preface to the previous volume as to the scope and time of appearance of the remaining portion of his work. Hence the explanation in the preface of vol. iii that the promised account of the geographical distribution of plants at different stages in the history of the earth has been crowded out of vol. iii and the following vol. iv, now in the press, and must therefore form the subject of a separate book. This is all to the good from the students' point of view; the subject of geographical distribution in time, if treated in the full and careful manner which we expect from Professor Seward, may well form a separate volume. We trust that the leisure which one associates with the mastership of a college in an ancient university may allow of its speedy completion. Like the growing point of a Monocotyledon, the scope of Professor Seward's undertaking has broadened with its growth, and the completed work will form a landmark in the literature of palæobotany.

The present volume opens with a general account of recent Cycads, the headline to which contains a curious misprint, one of the very few we have noticed in the volume, the general production of which is excellent, with clear and well-arranged text. The account of the Pteridosperms was begun in vol. ii, but the treatment of the better-known genera was reserved for the present volume; "as these genera are founded to a large extent on anatomical characters oscillating in their essential features between recent Ferns and Cycads," this intercalation of a chapter on recent Cycads was a happy thought. In the second chapter the author resumes his descriptive account of the Pteridosperms. These are considered under the headings Lyginopterideæ and Medulloseæ. Under the former is a full description of *Lyginopteris* (a name which on principles of nomenclature replaces the somewhat better-known *Lyginodendron*), including vegetative and reproductive organs, with the seed which was formerly known as *Lagenostoma.* The subject of nomenclature is a difficult one for the writer of a textbook on palæobotany. Having pieced together the fragments which have been described under different names at different times, he has to decide what name the more or less perfect entity shall bear; and it must sometimes happen that a better-known name must give place to one which is for the moment less well known. Professor Seward is wise to be guided by definite principles; in a book like the one before us, which will be a standard textbook for some time, he has the opportunity of fixing a name for the use of students.

In this chapter the author discusses the use of the term "seed" for the structure represented by *Lagenostoma* and other Palæozoic seeds. The difficulty is the absence of an embryo, a very important feature, the development of the embryo being the outward and visible sign of the process of fertilization. The opinion is expressed that this negative character should not be allowed to outweigh the evidence furnished by morphological features as to the applicability of the term seed (p. 61). Later (p. 301) the writer refers to "the promotion of the megasporangium and megaspore of the Pteridophyta to the higher stage represented by the integumented megasporangium (nucellus) and single megaspore that in the main fulfil the definition of a seed". How, then, shall we define an ovule? The seed of the modern phanerogam or seed-plant is so characteristic and morphologically well-defined a structure that one somewhat regrets the application of the same term to these early attempts to achieve the same biological function. Professor Seward is not, we think, quite sure of his position, as on each occasion he leans on the stalwart arm of Professor Oliver. As Professor Oliver says, "there is a long chapter in evolution to be deciphered before we can connect . . . the seed of *Lyginodendron* with the sporangium of any fern at present known to us." We might add, there is a long long trail between *Lyginodendron* and the modern seed-bearing plant.

The account of *Heterangium* and the associated seed *Sphærostoma* follows that of *Lyginopteris*, after which is a chapter on Medulloseæ and the *Trigonocarpus* seed-type. The Lyginopterideæ and Medulloseæ are regarded as offshoots of a common stock, the latter occupying a position farther removed from the filicinean ancestry than the former.

Under the heading Cycadofilices is a description of several types represented by stems, but which in the absence of definite information with regard to the reproductive organs cannot be assigned to the Pteridosperms, including among others *Megaloxylon*, *Cycadoxylon*, *Calamopitys*, *Cladoxylon*, and *Protopitys*; their structure is well illustrated by photographic reproductions of sections and diagrammatic figures.

The two following chapters are devoted to the Cordaitales under the headings Poroxyleæ, comprising *Poroxylon*, Cordaiteæ, including *Cordaites* proper with some allied or imperfectly known genera, and Pityeæ, including the large petrified stems known as *Pitys* and other genera founded on stems of comparable structure. A chapter on Palæozoic gymnospermous seeds forms a useful comparative study of selected examples illustrating the remarkable variety in details of external form and internal structure associated with certain fundamental features which they have in common. Here, again, the illustrations are most helpful.

The concluding chapters deal with the fossil Cycadophyta. These are represented by the important class Bennettitales and include *Cycadeoidea* (more generally known as *Bennettites*), *Williamsonia*, the recently described *Williamsoniella*, and other less perfectly known genera; these forms are fully and carefully described. A chapter follows dealing (1) with Cycadean stems other than *Cycadeoidea*, the best known of which are those assigned to *Bucklandia*, and (2) with reproductive organs of fossil Cycadean plants which cannot be assigned to Bennettitales. Some of these, which have been described by various authors as *Carpolithus*, agree in external features with the seeds of modern Cycads, but in the absence of anatomical details their position must remain doubtful.

The last chapter, Cycadophytan fronds, contains a description of a number of genera founded on detached leaves which are believed to be Cycadean.

A list of works referred to in the text (including vols. iii and iv), arranged alphabetically under the author's name, occupies nearly fifty pages.

A. B. Rendle.

II.—Cambridge County Handbooks.

Bedfordshire. By C. Gore Chambers. Cambridge County Handbooks. pp. x+195. Cambridge University Press. 1917.

Although Bedfordshire is one of the smallest of the English counties, nevertheless it shows a surprising diversity of natural features and productions. This diversity is closely correlated with the geological structure of the district. From this point of view the county may be divided into three sections; firstly, the Jurassic clays of the north, which form low, gently rolling, or flat ground, mainly occupied by the valley of the Ouse; secondly, the conspicuous ridge of the Lower Greensand, with its pine-woods and heather, extending across the county from Leighton Buzzard to Potton and Sandy; and, thirdly, the Chalk downs of Luton and Dunstable, which rise at Kensworth Hill to a height of some 800 feet, and afford an excellent example of the Down type of scenery. Some of the superficial deposits of Bedfordshire are also of considerable interest, notably the gravels of Biddenham, which have long been classical in the study of Palæolithic man in Britain. It was here that the results obtained by Boucher de Perthes on the Somme were first established and extended for Britain. This discovery formed a notable landmark in the history of prehistoric archæology.

In this small book Mr. Gore Chambers has given a concise and well-arranged account of the natural features and products, archæology, and history of Bedfordshire, showing clearly how the development of population, communications, and industries is closely dependent on the geography and geology of the district. Although not containing within its borders any places of paramount importance, Bedfordshire was even in very early days an important centre on lines of communication, since the Icknield Way and the Watling Street crossed at Dunstable. These great roads are no doubt very ancient, probably going back to Neolithic times. Again, the Stane Street, an important road from London to the North, skirted the eastern side of the county, while the town of Bedford was an important stronghold at an early date.

The mineral wealth of the county is not great; the coprolite industry and the quarrying of the Totternhoe Stone for building purposes are now almost or quite extinct, but the sands of the Lower Greensand have been largely used for glass-making and other commercial purposes; this is an industry that is likely to increase in the future. Near Leighton Buzzard there are beds of pure white sand of very good quality for glass. The yellow iron-stained sands of Sandy and other districts are chiefly used for building, iron-moulding, and filter-beds. Bedfordshire is on the whole an agricultural county, and the experimental work carried on at Woburn is world-famous. The alluvial soils of the Ivel Valley are specially suitable for market gardening, and of late years an enormous trade has sprung up in garden produce for the London market, ordinary garden vegetables being here grown by hundreds and thousands of acres. It is clear, therefore, that the industrial prosperity of Bedfordshire is largely founded on a geological basis.

R. H. Rastall.

III.—Persistence of Vents at Stromboli and its bearing on Volcanic Mechanism. By H. S. Washington. Bull. Geol. Soc. America, vol. xxviii, pp. 249–78, pls. vi–ix.

In this paper the author has brought forward the evidence of the constancy of position of the vents on the crater terrace of Stromboli. By a careful comparison of old plans and sketches, going back as far as 1776, he has established the fact that certainly three, and probably more, of these vents have not altered their positions to any appreciable extent since that date. He compares with this the constant position of the lava lake, Halemaumau, in the crater of Kilauea, and suggests that there is some evidence for a similar constancy at Vesuvius and Etna, though here the information is much less definite.

From these facts the author draws the following conclusions: (1) The vents are the openings of conduits which have pierced through the solid rock for the greater part of their courses. (2) The lengths of these conduits must be considerable, for, if this were not so, we should expect vents to break through the thin crust at various places at different times. (3) The persistence and relatively small size of the vents, which must be wider than the conduit, indicate that there has been very little corrosion of the vent by the uprising magma, which is presumably kept fluid at a lower temperature than the melting-point of the surrounding walls, owing to its dissolved gases. (4) The complete absence of synchronism in the activity of the different vents shows that they communicate individually with the magma reservoir. (5) Judging by the size of the vents the conduits cannot be more than "a few tens of metres" wide.

These conclusions, together with the fact that the vents occur at the top of a scarp more than 2,000 feet high (probably caused by the subsidence of the north-west portion of the original crater), lead the author to adopt Daly's "gas-fluxing" hypothesis to explain their formation. This hypothesis is briefly described as follows: Gas bubbles rise to the top of the magma in the reservoir and accumulate in irregularities ("cupolas") in the roof. These gases are supposed to be at a higher temperature than the magma owing to their exothemic interactions and so "blowpipe" their way up through the overlying rock. The action of these gases will only extend over a small area, so that many narrow independent pipes will be formed. This hypothesis is especially applicable to the formation of the vents on the Stromboli crater terrace, if this has been formed by the sinking of a large mass to the north-west, since the magma reservoir may be assumed to have maintained its original level under the remaining centre part of the original mountain, which would then be the most favourable place for the "gas-fluxing" action to take place.

The paper is illustrated by some very interesting photographs, sketches, and reproductions of illustrations from the old books dealing with the volcano.

W. H. W.

IV.—The Eruption of Sakura-jima on January 12, 1914. By Charles Davison, Sc.D., F.G.S. *Science Progress*, No. 45, July, 1917, pp. 97–110.

In *Science Progress* for July, 1917, Dr. Davison gives a very interesting summary of Professor Omori's investigations[1] into the eruption of Sakura-jima which took place in January and

[1] "The Sakura-jima Eruptions and Earthquakes": Bulletin of the Imperial Earthquake Investigation Committee (Tokyo), vol. viii, pp. 1–34 (1914), 36–179, 181–321 (1916).

February, 1914. Sakura-jima is an island, one of a series of five volcanoes situated along a N.N.E.–S.S.W. line on or near the southern end of the island of Kyushu, which is the most southerly of the main islands of the Japanese Empire. The activity of the Japanese volcanoes is restricted to certain periods, separated by more or less long periods of quiescence; and in this present active period 194 eruptions occurred from eleven volcanoes between 1909 and 1914. The eruption was preceded by the usual premonitory warnings, the significance of which was so completely understood by the authorities that the whole population of the island, some 23,000 in number, were removed with the loss of only three lives. The paroxysmal phase was one of extraordinary violence; it began with the ejection of stones and ashes from one of the main craters, which was followed somewhat later by the outpouring of lava from two groups of craterlets on the west and south-east sides of the island; it was also accompanied by a severe earthquake, which was recorded by European observatories, and by a small earthquake wave, which was probably caused by the subsidence of the bottom of the neighbouring Kagoshima Bay.

Detailed surveys of the district, before and after the eruption, show considerable elevation (between 30 and 40 feet) of the mass of the island itself and subsidence of from 4 to 20 inches over the surrounding country. These displacements require the sinking of a mass of the crust of at least half the volume of the material ejected during the eruption. The sound phenomena were found to behave in a normal manner, that is to say that there were two zones, one near and one far from the volcano, in which the sounds were separated by a silent zone, the middle line of which lay about 75 miles from the mountain. The chief eruption of Sakura-jima was associated with eruptions from the other vents in the line. Three out of four of these were active between January 8 and March 21, beginning with the most northerly and ending with the most southerly.

W. H. W.

V.—The Colour of Amethyst, Rose, and Blue Varieties of Quartz. By T. L. Watson and R. E. Beard. Proceedings of the United States National Museum, Washington, 1917, pp. 553–63.

Up to the present time but little information is available as to the cause of the disperse colours of minerals, as distinguished from the colours due to the actual chemical constituents of the mineral itself. The authors of this paper have made a careful investigation of the chemical composition and physical structure of variously coloured varieties of quartz with a view to discovering the reason of the wide variations that exist in different types. The principal constituents found which might give rise to colour are manganese, titanium and iron, with traces of cobalt. On the average of thirteen analyses it was found that amethyst contains the highest percentage of manganese, while rose quartz has the highest percentage of titanium; the quantities are, however, very small, ranging from ·0005 to ·0031 per cent, while iron does not exceed ·006 per cent. The authors believe that the colour of amethyst is mainly due to manganese, which probably exists in the form of colloidal particles of ultramicroscopic size, consisting of manganese oxide. Since the colour of rose quartz when destroyed by heat cannot be restored by daylight or by exposure to radium, it is considered not to be due to any inorganic substance.

The cause of the peculiar blue colour of quartz from Virginia was also investigated. This is found in a highly titaniferous petrographical province, and the colour is believed to be in the main an interference phenomenon due to the scattering of light by minute [illegible] with crystallographic regularity. This is [illegible] our of the quartz of the [illegible] Heating does not destroy [illegible] coloured varieties are com- [illegible] rized by heating to about 1100° C. for ten minutes.

[illegible] investigation is an interesting and suggestive piece of work, which is well worthy of imitation on other minerals whose colour is due to minute quantities of some foreign substance. By way of criticism it may perhaps be suggested that the authors have scarcely paid sufficient attention to the possible influence of the iron oxides present in determining the colour of these varieties of quartz.

R. H. Rastall.

VI.—The Magnesite Deposits of Grenville District, Argenteuil County, Quebec. By M. E. Wilson, Geological Survey of Canada. Ottawa, 1917.

In recent times magnesite has become increasingly important as a refractory mineral for metallurgical purposes, and during the last three years a demand has sprung up in America for a supply from home sources, most of the material used having been formerly imported from Austria and Greece. This has led to the development of a considerable industry in Quebec. The magnesite is found in the rocks of the Grenville Series, the oldest subdivision of the Pre-Cambrian of the district. These were originally sediments consisting of sandstone, shale, and limestone, which have undergone an intense degree of metamorphism; the limestones have been converted into crystalline marbles, partly dolomitic, while some varieties contain a proportion of magnesium carbonate in excess of that required to form dolomite; some samples show as little as 7 per cent of lime. From the descriptions given in this memoir it appears that the enrichment in magnesia may be due in part at any rate to intrusion of masses of pyroxenite and other basic rocks rich in magnesia connected with the Buckingham Series. The process may have been effected largely by the aid of pneumatolytic solutions arising from basic or ultrabasic magmas. The magnesite is largely associated with serpentine and diopside rocks, and the whole has been crushed by dynamic metamorphism into lenticular masses of varying size and composition. Petrographically the rocks are of great interest: the minerals present include many of those characteristic of areas of dedolomitization by igneous intrusions. The total amount of magnesite now in sight is estimated at about 1,000,000 tons, and there may be a good deal more under certain drift-covered areas.

R. H. R.

VII.—A Review of Mining Operations in the State of South Australia during the half-year ended June 30, 1916. Compiled by Lionel C. E. Gee and issued under the authority of the Honourable the Minister of Mines. Adelaide, 1916.

THIS report deals with the mineral production of South Australia during the above-mentioned half-year, the minerals with which it is concerned being mainly copper, gold, salt, and some silver lead. The search for copper has been stimulated by war demands, and gold returns are recorded as improving. Logs and detailed sections of a number of deep bores which were put down in search for copper are given. Unfortunately these were not successful in striking any valuable copper deposits. The rocks passed through were mainly quartzite, mica-schist, and gneiss.

Interesting accounts are given of the prospecting for tungsten minerals at Callawonga Creek and of a survey of the hundred of Kongorong, which was carried out to determine the advisability of boring for petroleum. At Callawonga Creek valuable deposits of ferberite are found, in conjunction with tourmaline, in veins which are intermediate in character between pegmatite and quartz veins. The distribution of the mineral is irregular and in some places it is associated with finely divided gold. Work has been carried out to a considerable extent on the surface and the field seems suitable for deeper work.

The survey of the hundred of Kongorong is a striking example of the advantage of calling in reliable expert advice before undertaking any enterprise. Petroleum seepages were reported from this district, which rested on the evidence of a specimen of asphaltic bitumen, which was said to have been discovered there. It was also alleged that the structure of the country as shown by the "ranges" was suitable for the accumulation of petroleum deposits. The Government geologist found, on surveying the district, that the "ranges" were nothing more than parallel lines of dunes formed during the gradual elevation of the coast, and that the only solid rock which could be detected, over most of the area, was a polyzoal limestone, which was proved by boring to rest on sands and clays with lignite. These were apparently fairly horizontal, and no clue as to the real structure of the district could be obtained. Moreover, no traces of petroleum were found, and it is supposed that the facts of the discovery of the bitumen were not strictly accurate. The result of this investigation was that no work was undertaken, and money saved which would otherwise have been thrown away on a useless enterprise.

The review is illustrated by photographs of the mining operations and of the Kongorong dunes.

W. H. W.

VIII.—The Wolfram Mines of Bamford and Carbine Hill, North Queensland. By L. C. Ball, B.E., Assistant Government Geologist. Geological Survey of Queensland, Publications No. 248 and 251.

These two small mining fields in the North of Queensland produce mainly wolfram, though they also contain a certain amount of molybdenite and tinstone and at Bamford bismuthite. The latter field has been in operation since 1893 and has produced in addition to other minerals about 1,580 tons of wolfram concentrates, while the Mount Carbine field produced about 670 tons between 1906 and 1912. The production of both fields was, at the time of writing, on the down grade, since the rich surface ("Shoad") deposits were exhausted and the deep veins had not been fully exploited owing to lack of capital and difficulty of working.

The ore in both cases occurs in veins associated with granites. At Mount Carbine, where the country rock is mainly slate, the mineral veins are found in the slates; while at Bamford, where the granite is intrusive into massive porphyry, the veins are generally situated in the granite itself, near the contact zone, and are accompanied by greisenization and the formation of quartz rock. At Bamford the veins often widen out into "vugs" or broad cavities filled with quartz, which is the chief "gangue", and metalliferous minerals. Following the ideas of Daly and Van Hise and also the experiments of Fouqué and Michel Levy, the author puts forward the hypothesis that the silica was originally introduced into the veins in the colloid state. In this condition it would allow the free passage of the mineralizing gases, but, as the jelly became viscous, the gases would be trapped and attack the side walls of the veins, forming "vugs". Finally the silica was probably precipitated in the crystalline form owing to the action of tungstic acid, since this has been shown to exercise a similar action on albumin.

The author describes the mining properties in detail and also the methods of dealing with the ore, the supplies of water, timber, and other necessaries of mining communities. The memoirs are illustrated by photographs of the scenery and the mines, and also by diagrams of the most interesting vein phenomena.

W. H. W.

IX.—The Satsop Formation of Oregon and Washington. By J. Harlen Bretz. *Journal of Geology*, vol. xxv, 1917, pp. 446–58.

The Satsop formation is the name given to a series of deposits composed of sands and gravels with occasional beds of clay and lignite, which is found in the valleys of the rivers of Washington and Oregon. It occurs along the coast, in the valleys of Coast Range, in the valley between the Coast Range and the Cascade Range, and in the gorge cut through the Cascade Range by the Columbia River. It rises from sea-level, or below, on the coast to the height of 3,000 feet in the Cascade Range, and belongs to the cycle of denudation previous to that now in operation. It was evidently deposited after the uplift of the Coast Range, as it forms terraces along the valleys cut across this range and also terminates abruptly against its eastern slope. But in the gorge of the Columbia River which is cut through the Cascade Range it rises above the river-level, as it is followed eastwards to the centre of the range, where it begins to fall, and is found on the eastern side to be again at or near river-level. It here contains a lava-flow, and is at one place covered by another. It rests unconformably on the denuded edges of some of the earlier anticlines.

From this it is seen that the Satsop formation is later than some of the folding of the range, but earlier than the final uplift. The Cascade Range has been shown by Russell and others to be an uplifted, dissected peneplain, which has been called the Methow peneplain, and the author correlates this with the surface on which the Satsop formation rests.

By the fossil content of the clays and lignites which it contains it is shown to be of late Pliocene or possibly Pleistocene age. This determination would show that the final uplift of the Cascade Range took place either in very late Pliocene or Pleistocene times.

W. H. W.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

Dr. Flett, President, in the Chair.

The following paper was read on March 21, 1917 (Abstract received October 12, 1917): "Geology of Kinkell Ness, Fifeshire" (with lantern illustrations). By D. Balsillie, B.Sc., F.G.S.

The largest, best exposed, and most interesting volcanic vent along the northern shores of Fife is that which has been laid bare at the headland of Kinkell Ness, and a portion of the enclosed material of which has been sculptured into the picturesque shore stack known as the Rock and Spindle. The margins of the vent were first referred to by the author, these being easily traceable, he said, except on the southern and western sides where the fragmental accumulations of the neck pass into the grass-covered cliff line above high-water mark. Thereafter the character and arrangement of the materials filling the old volcano were described in some detail, special attention being called to the occurrence in the agglomerate of numerous blocks of a white coral-bearing limestone that probably belongs to the base of the Carboniferous Limestone Series—this being a higher stratigraphical horizon than any of the rocks now surrounding the vent.

Though, as emphasized by Sir Archibald Geikie, there is no evidence to show that lava streams were ever emitted at this volcanic centre, the uprise of igneous material in the chimney is impressively demonstrated by the masses, dykes, and veins of igneous rock that ramify through the ash. Some of these intrusions have caught up such a quantity of extraneous fragments that their simulation of true agglomerates is very striking and apt to be exceedingly misleading.

The petrographic characters of the basalts are not easy to ascertain on account of their altered state. Drs. Flett and Campbell are agreed that, although nepheline cannot possibly be determined in any of the author's micro-sections, yet the general resemblance of the latter to those of the felspathoid-bearing basalts of the St. Monans and Elie district is so remarkably close as probably to place beyond question their related origin.

When discussing the geological age of the Rock and Spindle vent, the author said he was inclined until recently to concur with Sir A. Geikie in placing it along with other East Fife necks in Permian or, at all events, in post-Carboniferous time. Revision of this opinion would, however, now appear necessary. A careful examination of the Spindle basalt reveals the exceptionally interesting fact that there are enclosed in it, apparently directly, numerous fish teeth in a condition of excellent preservation. Dr. Peach believes he has identified *Megalichthys* and *Psammodus* in the specimens collected. Should these fossils, on fuller investigation, prove not to be derived, then the vent must be carried back in age to the period of the Carboniferous Limestone.

CORRESPONDENCE.

SALT-WEATHERING AND SUPPOSED WORM-BORINGS IN AUSTRALIA.

Sir,—The interesting notice, signed W. H. W., of Mr. E. J. Dunn's "Geological Notes, Northern Territory, Australia" (Geol. Mag., March, 1917, p. 134), led me to communicate with Mr. Dunn, who has kindly sent me copies of his recent papers, on which I venture to offer the following remarks.

The appearance of contortion observed on the surface of a two-inch core in presumed Carboniferous rocks, and interpreted by Dr. Jensen and Mr. Dunn himself as due to the borings of worms, reminds one rather of some pieces of the Cotham Stone or Landscape Marble (see Horace B. Woodward, Geol. Mag., March, 1892, p. 110). The rock before its disturbance appears to have consisted of thin layers of sand alternating with thin layers of black shale. The latter, being carbonaceous, may well have contained in places a considerable amount of decaying organic matter. Consequently the explanation of these disturbances may be the same as that put forward by Mr. Beeby Thomson for the Cotham Marble (August, 1894, Quart. Journ. Geol. Soc., vol. 1, pp. 393–410). That is to say, bubbles of gas springing from the decomposing carbonaceous matter pass through the overlying laminæ and throw them into confusion. When the streams of bubbles are concentrated in definite places naturally a tubular form is assumed; hence the resemblance to worm-borings.

Here one may recall the somewhat similar explanation which Professor A. G. Högbom has given of the Scolithus sandstone and the Pipe-rock (1915, Bull. Geol. Inst. Upsala, vol. xiii, pp. 45–60). And it is perhaps appropriate to mention here that in 1911 Mr. W. H. Twelvetrees, Government Geologist of Tasmania, sent to the Natural History Museum two specimens of "pipe-stem sandstone" of supposed annelid origin, but showing in thin section no structure other than grains of sand. "For the most part," said Mr. Twelvetrees, "the tubes are vertical to the bedding, but occasionally we find them parallel to it. Sometimes they are as thick as a pencil. Sometimes they are trumpet-shaped. At one time we thought they were restricted to one geological horizon, but they evidently persist from our Cambrian or Cambro-Ordovician conglomerate, in which they occur sparsely, through the sandstone of doubtful Cambrian or Ordovician age to Silurian sandstone, in which they are also rare." The specimens are now in the Geological Department, registered A 1658.

In a reply to Mr. Twelvetrees, dated September 30, 1911, I compared the specimens with similar structures in the Cambrian sandstones of this country and of Sweden, in particular with a specimen obtained by me at Bergquara in Småland (Brit. Mus., Geol. Dept., A 1356), where such appearances are fairly common and have been referred to *Scolithus linearis*, Hall. Descriptions of these are given by N. O. Holst (1893, *Sveriges Geol. Undersökning*, ser. C, No. 130, p. 6) and Nathorst (1892, *Sveriges Geologi*, p. 117 and text-figures on p. 118). Though usually interpreted as the filled burrows of worms, Nathorst questions whether the structure has not rather arisen in a mechanical way. The cylinders are often packed so closely that I too was "inclined to regard the structure as due to some mechanical agency". Some American specimens in the British Museum, labelled *Scolithus*, do indicate the existence of burrows subsequently filled; but in the pipe-rock there is no evidence of this. I do not, however, understand how the tubes can ever be parallel to the bedding, as stated by Mr. Twelvetrees, if formed by ascending bubbles.

In another note (Proc. Roy. Soc. Victoria, N.S., vol. x, pp. 209–10) which Mr. Dunn published in May, 1898, he was tempted to ascribe numerous perforations in a decomposed steatitic rock near Coolgardie to worms, larvæ, or flies. He mentions, however, that the roots of eucalyptus trees follow these perforations to as great a depth as 150 feet from the surface. May it not be the case that the perforations were actually made by the eucalyptus roots? Such an action is by no means uncommon.

The weathering action of salt-solution through repeated wettings and dryings is one that I have attempted to apply in removing the matrix from the surface of fossils, or inducing differential weathering of a fossiliferous limestone with impure matrix. The mechanical principle of crystallization involved in the weathering is, as Mr. Dunn says, an intensification of the principle of repeated freezing and thawing in winter, and is more convenient for the palæontologist. The same effect may be attained by the use of the more readily crystallizing salt, sulphate of magnesia (Epsom salts). It is, however, a question whether there may not be in the case of sodium chloride some chemical action as well. Here reference may be made to the paper read by Professor R. C. Wallace at the Manchester Meeting of the British Association, 1915, "On the Corrosive Action of certain Brines in Manitoba." The third paragraph of the Abstract (published in the Association Report, p. 427, and in the Geol. Mag., Jan. 1916, p. 31) indicates a considerable chemical action, due to the fact that a persistent film of concentrated sodium chloride acts in conjunction with the gases of the atmosphere. The evidence for all this is presumably given in Professor Wallace's complete paper, but I do not know whether that has yet been published. In the case of Mr. Dunn's pebbles, instead of a persistent film there is regular alternation of wet and dry, so that the chemical action, if any, must be considerably less than the mechanical; mere attrition appears to be excluded.

F. A. Bather.

OBITUARY.

FRANÇOIS CYRILLE GRAND'EURY.

Born March 9, 1839. Died July 22, 1917.

By the death of M. Grand'Eury palæobotany loses one of its most distinguished and energetic pioneers. As a mining engineer who spent his life in coal-fields, he had unrivalled opportunities for observing Carboniferous plants in situ, and he always made the most of every discovery which came under his notice. His special studies enabled him to correlate various roots, stems, foliage, and fruits which as isolated fossils had received separate names. He also made many important observations bearing on the origin of coal. His well-known memoir on the Carboniferous Flora of the Loire was published by the Paris Academy of Sciences so long ago as 1876. His great work on the Coal Basin of the Gard appeared in 1890. Numerous other publications culminated in his *Recherches géobotaniques*, which were in course of issue at the time of his death.

PROFESSOR EDWARD HULL,

M.A., LL.D., F.R.S., late Director Geological Survey of Ireland, and Professor of Geology Royal College of Science, Dublin.

Born May 21, 1829. Died October 18, 1917.

We regret to record the death of Professor Hull, at his residence, 14 Stanley Gardens, Notting Hill, W. 11, on October 18, aged 88.

A memorial service was held on Monday, October 22, at St. Peter's Church, Kensington Park Road, Notting Hill, and was attended by numerous representative scientific men.

A record of his life-work as a geologist will appear in December.

GEORGE C. CRICK,

Assoc. R.S.M., F.G.S., of the Geological Department, British Museum (Natural History).

Born October 9, 1856. Died Octoer 18, 1917.

With sorrow we record the death at his residence, 20 Bernard Gardens, Wimbledon, in his 62nd year, of our former colleague, Mr. George C. Crick, well known as an authority on the fossil Cephalopoda, and author of numerous papers in this Magazine, the Proceedings of the Malacological Society, and the Quarterly Journal of the Geological Society.

A notice of Mr. Crick's scientific work will appear next month.

H. W.

All Communications for this Magazine should be addressed to

THE EDITOR,

13 Arundel Gardens, Notting Hill, W. 11.

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OR

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THE GEOLOGIST.

EDITED BY

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

ASSISTED BY

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DR. GEORGE J. HINDE, F.R.S., F.G.S.
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DECEMBER, 1917.

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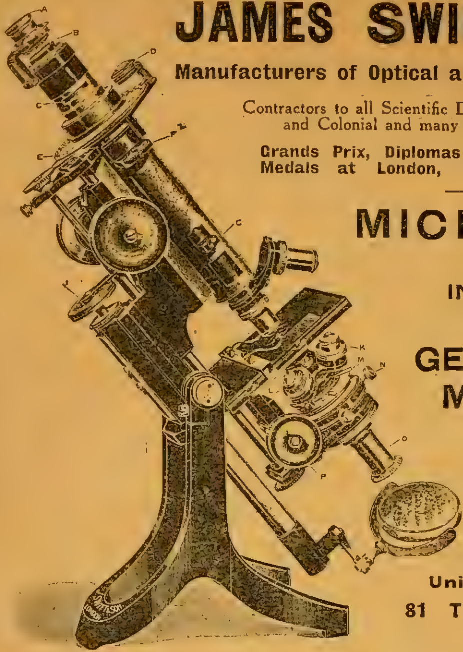

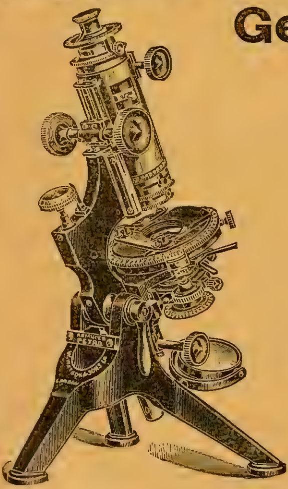


SKETCH MAP OF AMBRYM
The main outline is after the Survey by H.M.S "DART" under Admiral Purey-Cust in 1913. The altered outline in the north-western corner & the lava flows of the 1913-1914 eruptions are after the Survey by H.M.S "Sealark" under Commander Hancock.
Lava flows & boundaries of main lava field of 1894 eruption.
Lava of 1913 & Jan. 1914 eruption.
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Mt Tuyio 3820'
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Sealark Hill 330'
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Old Crater
1894'
1210'
1310'
1420'
Dip Pt.
Minnei Peak
Foluk
Craig Cove
Lava Pipe
Baulap
Baulap
The Morne 860'
P. Vato
Vato Lava Pipe
3585'
2415'
2165'
2185'
2270'
2790'
3325'
2450'
2800'
4380' Mt Marum
2100'
small crater
Mt Benbow 3720'
Vents on floor
Great Ash Plain level about 2100'
Cascade
Volcano 1190'
lava flow 1899
S.E. Point
Geographical Miles
0 1 2 3 4 5

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. XII.—DECEMBER, 1917.

ORIGINAL ARTICLES.

I.—The Ambrym Eruptions of 1913–14.[1]

By Professor J. W. Gregory, D.Sc., F.R.S.

(WITH A MAP, PLATE XXXIII.)

1. The Constituents of the New Hebrides.
2. The Volcanic History of Ambrym to 1894.
3. The 1894 Eruption.
4. The Features of the 1913 Eruption—
   (a) The Explosion Trough.
   (b) The Lava Pipes.
   (c) The Fissure Eruptions.
5. The Rocks of the 1913 Eruption.
6. General Relations of the Ambrym Eruptions.
7. References.

1. The Constituents of the New Hebrides.

THE rocks of the New Hebrides belong to at least four groups—two series of limestones and two series of volcanic rocks. The islands are sometimes referred to as if composed only of recent volcanic and coral formations. The existence of a series of old rocks has been believed from the records of gneiss on Espiritu Santo by Levat, and of ores of iron, copper, and nickel. The asserted presence of these materials suggested that the older rocks of New Caledonia form the foundation of the New Hebrides. The existence of the ores and gneiss is, however, discredited by Sir Douglas Mawson (1905, pp. 422, 434–5); he remarked that he had examined "small samples of copper, manganese, and other ores *supposed* to have been collected in the group" (Mawson, 1905, p. 435). He did not confirm this supposition, though admitting that traces of these metals might occur.

Lieut. Frederick (1893) obviously identified some of the New Hebrides rocks as "claystones", which may indicate that he recognized some older sediments. If this statement had been confirmed it would have been his most important contribution to the geology of the archipelago; but it was apparently distrusted, and was excluded from his published paper; and his identification is only known from a remark by Sir Archibald Geikie in the discussion.

[1] [The description of the Volcanic Eruption of 1913 on Ambrym Island, New Hebrides, by the Rev. M. Frater, appeared in the Geological Magazine for November, 1917, pp. 496–503, and was communicated by Professor J. W. Gregory to the Editor.]

Although the existence of the suspected early rocks is unconfirmed, Sir D. Mawson collected at Espiritu Santo a series of limestones which Mr. Chapman (1905, p. 273) identified by their Foraminifera (*Lepidocyclina*) as Aquitanian and Burdigalian. They are therefore Lower Miocene, and would be also Upper Oligocene according to the classification which refers the Aquitanian to the Oligocene.

These *Lepidocyclina* limestones are shown by Mawson to rest on an older volcanic series, which he attributes to the Oligocene or the base of the Miocene. The limestones are burst through by a later volcanic series, the earlier tuffs of which Mawson regards as possibly Pliocene. These tuffs form the beginning of the volcanic period that includes the modern eruptions.

The Miocene rocks occur in south-western Espiritu Santo, and their arrangement shows that they are part of a great upfold which formed the New Hebrides ridge.

The later limestones are recent coral reefs. Some of them have been raised high above sea-level. On Efate (Sandwich Island) limestones, which are regarded as raised coral reefs, occur 1,500 feet above sea-level (Frederick, 1913, p. 227).

The bulk of the archipelago consists of volcanic material belonging to the later eruptions. The archipelago is part of the great volcanic line which passes along the Pacific border of Australasia from New Guinea through the Solomon Islands to New Zealand. The New Hebrides volcanoes have been in frequent eruption. Tanna, as Mr. Frater remarks, is of the Strombolian type owing to its chronic activity since it was seen in 1774 by Captain Cook, who was the first European to visit the Archipelago. Ambrym was also then in eruption. Lopevi, to the south of Ambrym (4,755 feet high), is a smaller island with a regular volcanic cone. It was in eruption in 1864 (Purey-Cust, 1896, pp. 3–4). It is said to be the highest peak in the archipelago, though according to the *Sailing Directory, Pacific Islands*, vol. ii, 4th ed., 1908, p. 385, Espiritu Santo rises to between 5,000 and 6,000 feet.

2. The Volcanic History of Ambrym to 1894.

The eruptions on Ambrym occur at irregular intervals and include explosions of paroxysmal violence. The records collected by Admiral Purey-Cust (1896, pp. 5–6) indicate a disastrous eruption, which, judging from the probable age of the old man who remembered it, happened about 1820. Like the chief later eruptions, it was at the western end of the island; it poured lava into the sea at Craig Point. Moderate activity is recorded by the officers of a mission schooner, the *Southern Cross*, in 1870, and it is also reported as having been in eruption in 1883 or 1884 (Purey-Cust, 1896, p. 3). Lieut. Moore of the *Dart* stated that in 1883 large quantities of volcanic dust fell from Ambrym to the north and north-west of the island, but that no lava had been discharged for some years (Purey-Cust, 1896, p. 5). Mt. Marum, one of the two large craters in the middle of the island, was last active in 1888. A few months after it became dormant eruptions built up the crater known as "Volcano", of which the wall was breached by a lava stream, that reached the sea at the south-eastern corner of the island. The old crater of Mt. Benbow has apparently not been active in historic times until 1913; it was visited by Lieut. Beresford from H.M.S. *Dart* in 1883, when the small crater on the eastern side of Mt. Marum was mildly active (Beresford, 1884, p. 131).

3. The 1894 Eruption.

The first great eruption of which there is adequate knowledge occurred in October and November, 1894. Fortunately Commander, now Admiral, Purey-Cust had just completed a survey of the island in H.M.S. *Dart*, and he was able to observe the eruption from all sides of the island and to visit the most interesting localities. He published a most valuable report on the eruption, issued by the Hydrographic Department of the Admiralty, with an appendix upon the rocks by Professor Judd. Most of Admiral Purey-Cust's report was also published in the *Geographical Journal* (vol. viii, pp. 585–602).

For comparison with the recent eruption the chief features of that of 1894 may be summarized from Admiral Purey-Cust's report. That eruption began on the evening of October 15, though the glare then was attributed to a bush fire. Early on the 16th it was obvious that one of the volcanoes was in active eruption, for at daybreak a high cloud was suddenly projected from the centre of the island. A lava stream, marked by a line of burning bush, was flowing down the northern slopes. It reached the coast at 7.45 a.m., just east of Krong Point. Its entrance to the sea was watched from the *Dart* at the distance of 300 yards. The lava stream was from 20 to 30 yards wide, and a pillar of steam rose to the height of 4,600 feet. In the afternoon flames appeared to the south of the Mission Station of Lon-wol-wol at Dip Point, and most of the natives were transferred from the settlements there to the north-western part of the island. Next day, the 17th, the south-eastern crater, Volcano, was quiescent, and the natives at Dip Point reported "Fire he finish"; it continued, however, further east, for at 4 p.m. a cloud pillar was shot upward from Mt. Benbow to the height of 15,000 feet. On the 20th the natives were taken back to the settlement at Dip Point, as the danger there was over. Commander Purey-Cust landed with a party and walked from Dip Point along the track southward across the island; progress on the path was barred by two narrow lava streams flowing westward from a large sheet of lava to the west of the village of Fo-luk. The smaller stream was 10 feet high and was flowing at the rate of 4 or 5 feet per hour. The larger stream was 300 or 400 yards wide. On October 23 Admiral Purey-Cust visited the centre of the island and reached the northern edge of the Benbow crater. It had a flat floor, about a mile in diameter, surrounded by precipitous sides from 800 to 1,700 feet high. On the floor of the crater was a group of vents from which steam was rising to the height of 2,000 to 3,000 feet above the crater. On November 7 another explosion from Benbow hurled a column of dust-charged steam in ten minutes to the height of 26,000 feet. On November 21 the crater of Benbow was revisited and it was found that a fissure vent had been opened on its floor, no doubt by the explosion of November 7. Lieut. Dawson also on the 21st visited Mt. Marum. He described it as a perfect crater 1 mile east and west by three-quarters of a mile north and south, with very steep walls and a pool of water in the centre. It was therefore not active, but steam was rising from the small crater on the eastern side. Later eruptions of this series occurred at "Volcano", which was seen in eruption at the end of December, 1894, by the French man-of-war *Scorff*, and another eruption, apparently at the western end of the island, happened on February 10, 1895 (Purey-Cust, 1896, pp. 17, 18). The 1894 eruptions appear to have occasioned an uprise of 1 or 2 feet of the ground around Dip Point (Purey-Cust, 1896, pp. 21–2).

Admiral Purey-Cust concludes that this series of eruptions were confined to an approximately east and west line passing through Mt. Benbow, Fo-luk, and the western end of the island. At the north-eastern part of Ambrym even the earthquakes were slight, while neither the flow nor temperature of the hot springs on the northern and southern coasts was altered. Moreover, not only was Mt. Benbow active, while its neighbour, Mt. Marum, remained quiescent, but the two vents in the crater of Benbow, although only a few yards apart, seemed to lead from entirely different sources. He attributed the western eruptions to lava, finding no outlet in the centre of the island, having burst from the fissure where it traversed the lower ground at the western end.

4. The Features of the 1913 Eruption.

(a) *The Explosion Trough.*

The 1894 eruption was followed by nineteen years of comparative quiescence, though the vents on Mt. Benbow generally discharged clouds of steam. In December, 1913, a paroxysmal eruption followed on generally similar lines to the eruption of 1894, though with some more disastrous and remarkable effects. Mr. Frater's account shows that it began with a series of paroxysmal explosions followed by the emission of lava from a series of vents on an east and west line. The most dramatic episode of this eruption was the explosion which, like a mine, blew up the Mission Hospital of Lon-wol-wol. Admiral Purey-Cust (1896, p. 6) described the depression to the south of Dip Point, on the north-eastern side of Minnei Peak (1,245 feet), as a distinct old crater; he said it was half a mile in diameter, with an almost flat floor covered by scrub, bounded by perpendicular sides, and open, however, to the north. The new edition of the Admiralty Chart of Ambrym shows this crater better defined, for the breach on the north has been repaired. The main eruption of 1913 occurred to the north of this old crater on the plain formerly occupied by the Mission Station.

The chief line of modern volcanic activity on Ambrym through Volcano, Mts. Marum and Benbow, trends to the west-north-west, and if continued in that course beyond Fo-luk would pass under the site of the mission. The hospital was hurled into the air by an explosion just as that at Tarawera in New Zealand in 1886 blew up the Pink and White Terraces and scattered their fragments over the surrounding area. This explosion on Ambrym formed a volcanic trough more than a mile long by about a quarter of a mile wide, with its floor in places 50 feet below sea-level; as it is breached to the north, the sea has poured in and the site of the hospital is now occupied by a somewhat fiord-like inlet, which is T-shaped, and has a threshold across its entrance. Subsequently a submarine eruption built up the base of Sealark Hill, which has been raised to the height of 330 feet, and has extended the island for about half a mile seaward.

The change produced in the outline of this part of the island by the eruption is shown on the map, Pl. XXXIII; the broken line represents the original course of the coast, taken from the Admiralty Chart of 1894, and the full line represents the coast after the eruption of 1913 from the survey of H.M.S. *Sealark* under Commander Hancock.

(b) *The Lava Pipes.*

A second remarkable feature of these Ambrym eruptions is that the lava-flows are extraordinarily narrow in proportion to their length. Thus in the eruption of 1894 the lava stream which entered the sea near Krong Point was over 6 miles long. Admiral Purey-Cust (1896, pp. 7, 13, 16) records its width at four places—at the shore, where it was 20–30 yards wide; further inland, 30 yards wide; at its sharp bend east of Fo-luk, 30 yards wide; and at its upper part along its east to west course, where it was in places only about 10 yards wide (Purey-Cust, 1896, No. 1, p. 16; but said to be 10 feet wide in 1896, No. 2, p. 600). The lava sheet west of Fo-luk fed two streams which flowed south-westward; both are represented on the map as very narrow. The southern stream discharged from a tongue some 300 or 400 yards wide (Purey-Cust, 1896, p. 9) projecting from the wide lava sheet. The lava stream of 1913 which reached the sea at Baulap, flowed from the eastern end of the Fo-luk fissure; it was 5 miles long and is represented on the Admiralty Chart as a long narrow sinuous line. The discharge from the vent to the south-east of Mt. Marum formed a wide lava sheet, 3 miles in length from east to west, and nearly 2½ miles wide from north to south; at its western end it gave rise to a lava stream which was discharged in January, 1914, and reached the sea at Port Vato; its length was 5 miles, and it also is represented on the new edition of the Admiralty Chart as a long narrow stream.

The Admiralty Chart no doubt indicates only the approximate course of the lava streams, and it is not intended to give precise evidence as to their width. Exact information as to the width of the flows would be of value. The available evidence indicates that they are remarkably narrow. Admiral Purey-Cust remarks (1896, p. 13) that the stream west of Fo-luk flowed down a deep gully; and the narrowness of the streams is doubtless due to their being confined between the banks of steep gullies. A stream 6 miles long and maintaining an average width of 30 yards must be fed by the flow of material down the centre while the outside has cooled to form a solid pipe.

Admiral Purey-Cust has described the upper part of the Krong Point lava stream as hollow, since he heard the flow of a swift stream of water along the centre (1896, p. 17). He also describes (ibid., p. 13) the lava stream in the gully west of Fo-luk as concave; the upper surface has apparently sagged owing to the central lava having flowed away and left the roof unsupported.

The characteristic form of the lava-flows on Ambrym is therefore that of lava pipes, in which the length may be 300 times the breadth, rather than lava streams of normal proportions.

(c) *The Fissure Eruptions.*

The tubular structure of these lava-flows is the more remarkable as most of them appear to have been the result of fissure eruptions. According to the Rev. M. Frater the lava from the western vents discharged from a series of fissures, through which the lava quietly welled forth without violent explosions. Thus he says that near Meltungan "streams of lava literally gushed out of the fissures without intermittent explosions of steam". According to the usual conception of fissure eruptions they normally give rise to sheets of lava; but the Ambrym lava must have been so liquid that it discharged through the lowest outlet from the fissure like water from a reservoir; this phenomenon is well illustrated by the narrow stream which overflowed from the great lava sheet south of Mt. Marum and reached the sea at Port Vato. If the fissure had been opened on the top of the level plateau it might have formed a widespread lava sheet; but as each fissure was discharged through a lateral notch into some narrow gully it gave rise to a narrow lava pipe.

That the western eruptions of Ambrym in 1894 also were from fissures is indicated by the descriptions of Admiral Purey-Cust. He states (1896, No. 2, p. 600) that at Single Palm Hill "There was no regular crater, and it was evident that the lava had burst up from the ground in all directions, and had been either violently impelled up the hillsides by hydrostatic pressure, or else the hillsides had been themselves split open".

Another striking feature of the eruption was the contrast between the quiet discharge from the fissure near Fo-luk and the explosion from the western end of the same fissure at Lon-wol-wol. According to Mr. Frater the lava that escaped quietly from the fissures was as saturated with steam as that which was thrown explosively from the central craters. This difference was probably due to the varying amount of water in the ground traversed by the lava. The fissure near Fo-luk ran along the central ridge of the island a little to the south of the crest, which there rises in places to 1,210 and 1,310 feet above sea-level. This ridge being well drained on both sides was relatively dry. The only steam available at the eruption there was brought up by the rising lava. But the fissure at Lon-wol-wol was close to the coast and only slightly above sea-level. The ground there was probably saturated with water, and the ascent of the lava along this fissure produced superheated steam, which suddenly found relief in the explosion that formed the volcanic trough.

5. The Rocks of the 1913 Eruption.

The volcanic rocks of the New Hebrides, according to the previous records, vary from andesites to basalts or dolerite. Professor Judd (in Purey-Cust, 1896, p. 23) described the specimens collected by Admiral Purey-Cust from Ambrym and some adjacent islands as being all very typical augite-andesites and as strikingly uniform in petrographic character. The dominant felspar he identified as microtine. Sir Jethro Teall (Frederick, 1893, App., pp. 229–30), who determined the collection brought by Lieut. Frederick from the New Hebrides, identified the specimens from the "hot ground" at 50 feet above sea-level on Tongoa (one of the Shepherd Islands to the south-east of Api), and from Tanna as augite andesites; the rock from the summit of Tongoa, 1,584 feet, he identified as basalt, and a specimen from the island of Makura as a dolerite. According to Sir Douglas Mawson (1905, pp. 459, etc.) the volcanic rocks of the New Hebrides are mainly andesites and basalts, including a hornblende-andesite at Efaté, and a basalt-porphyrite from Mau, an island north-east of Efaté. He estimates (Mawson, Proc. Linn. Soc. N.S.W., 1905, xxx, p. 463) the mineral composition of the latter as follows: its chemical composition is given as No. 2 on p. 538.

	1st Generation. Per cent.	2nd Generation. Per cent.	Total. Per cent.
Felspar-intermediate labradorite, $Ab_1 An_1$	33	—	33
Felspar-basic andesine, $Ab_3 An_2$ (*sic*)	—	26	26
Pyroxene	—	24	24
Olivine	1·8	8·2	10
Magnetite	Inseparable		7
			100
Apatite			minute.

Some lavas from the 1913 eruptions collected at Dip Point, Ambrym, by Professor W. M. Davis, and others obtained by Rev. P. Milne have been described by Professor Marshall (1915); he identified them all as basalts composed of bytownite-labradorite, diopside-augite, sometimes grains of olivine, and a brown glass densely filled with magnetite dust. Professor Lacroix has also described the lavas from the 1913 eruption and determined them as augitic labradorites too poor in olivine to be true basalts. According to his determination the normative mineral composition is felspar 64 per cent, diopside 22 per cent, olivine 5 per cent, magnetite and ilmenite 9 per cent.

Professor Lacroix includes an analysis by Boiteau, which is quoted as No. 1 in the table on p. 538. He calls the rock an andose allied to camptonose, of a kind frequent among basaltic lavas and as nearly allied to those of Kilauea. Some of the old lavas thrown out by the eruption he says are true basalts.

According to Professor Iddings (1913, vol. ii, p. 648) the volcanic rocks of the New Hebrides are chiefly basalts with phenocrysts of olivine.

Mr. Frater's collection includes representatives of the chief 1913 and 1914 lava-flows, and the rocks are all basalts, are mostly glassy, and usually containing some olivine. The lavas represented are as follows.

The Baulap lava pipe, according to four specimens collected approximately equidistant along it, consists of olivine basalt and olivine-basalt glass.

The Craig lava-flow from the main fissures at Fo-luk discharged as a lava pipe down a gully; it then spread out as a wide sheet, from which a lava pipe descended almost to the sea near Craig Point. The specimens are very glassy basalts; in one of them I observed no olivine, which occurs, however, in a specimen from the lowest end of this flow near Craig Point.

The Lowea Valley lava-flow is a lava pipe that discharged north and north-west from the lava sheet, which also fed the Craig lava pipe; it is a very vesicular glassy basalt, with sparse olivine and larger augites.

Lava-flow from north of Fo-luk west-south-westward just south of "747 foot" hill. An olivine basalt with large augites.

Harbour Crater—from the trough formed by the explosion at Lon-wol-wol; a very vesicular glassy augite basalt.

South-east of Mt. Marum, from the vent of January 1, 1914, which formed the large lava sheet on the high plain to the south of Mts. Marum and Benbow, and fed the Port Vato lava pipe. Glassy olivine basalt with augite.

The typical rock of the 1913 eruptions, as represented in Mr. Frater's collection, is a basic lava, rich in black glass, and containing glomero-porphyritic groups of a basic felspar, which Mr. Tyrrell has determined as $Ab_3\ An_7$. The larger phenocrysts show zonal structure and are often deeply corroded. The groundmass is sometimes a dense black glass, and at others consists mainly of felspar laths with granules of augite and olivine. The olivine is usually in small grains, often enclosed in the radial groups of felspar, but it is sometimes in well-developed crystals. The proportion of olivine is small and in some sections none were observed.

Mr. Tyrrell has kindly examined the sections, and describes them as follows:—

"With the exception of slide D [from south of hill 747, west of Fo-luk] all the rocks consist of the same olivine-poor basalt, and differ only in texture, amount of glass, and vesicularity. In general the phenocrysts are comparatively sparse and small. They consist of plagioclase, augite, and olivine, named in order of abundance. The felspar is basic labradorite ($Ab_3\ An_7$), and is developed in curious little glomeroporphyritic groups with one or two crystals of olivine, rarely with augite. The augite is a yellowish-green diopsidic variety with extinction 40°. The groundmass, when dominantly crystalline, consists of granular augite and magnetite, with lathy felspars ($Ab_1\ An_1$). The augite + magnetite $\gtreqless$ felspar — a basaltic type of groundmass. Many of the rocks, however, contain a considerable amount of dark glass and are highly vesicular. In these glassy and vesicular varieties the felspar-phenocrysts appear to become more abundant relative to augite and olivine; and the olivine occasionally appears as tiny euhedral crystals in the groundmass. A very rough estimate of relative proportions in the most nearly holocrystalline varieties is—

Phenocrysts, 8 per cent.	
Labradorite (Ab_3 An_7)	5
Augite	2
Olivine	1
Groundmass, 92 per cent.	
Labradorite (Ab_1 An_1)	30
Augite	45
Magnetite	5
Glass + cryptocrystalline material	12

"Augite is decidedly more abundant in slide Bd [from the west end of the lava sheet east of Craig Cove] than in others of the same rock.

"Slide D is an olivine-basalt with much more abundant phenocrysts than the above. Olivine and augite occur in large crystals only slightly inferior to the felspar in quantity. Phenocrysts slightly $<$ or $=$ groundmass.

"The rocks are certainly basalts (olivine-basalts) in the modern acceptance of this term. The distinction between basalts and andesites is now made to rest more on the relative proportions of light (felsic) to dark (mafic) constituents rather than on the nature of the plagioclase or the presence or absence of olivine. The andesites have a decided predominance of felspars over ferromagnesian minerals, and the felspars are usually, though not necessarily, andesine or acid labradorite. The basalts are characterized by approximate equality of felsic and mafic constituents, and generally by basic plagioclase and presence of olivine. Thus one may have olivine-andesites with phenocrysts of basic plagioclase (a type very common in the circum-Pacific volcanoes), and basalts devoid of olivine and containing only moderately basic felspars."

The specimens collected by Professor Davis from Dip Point (Marshall, 1915, p. 391) and those brought by Mr. Frater from Harbour Crater agree in character with those from the lava streams discharged from the fissures at Fo-luk. They are all basalts of the same type. Hence the explosive or non-explosive nature of the eruption at Ambrym must depend, not upon the nature of the rock, but upon the conditions of its eruption, and probably on the character of the surface into which it was intruded.

Professor Lacroix refers to the specimens he examined as too poor in olivine to be true basalts, although they contained 5 per cent of olivine. This amount is above that in most of Mr. Frater's specimens, in which Mr. Tyrrell determined the percentage of olivine as only one. Professor Lacroix identified the specimens he investigated as andose. The identification is of course correct, but the name is inappropriate, since, according to Professor Iddings (e.g. 1913, ii, p. 615), andose is a basalt and not an andesite, the natural affinity suggested by the name. Probably the older Ambrym lavas associated with the more explosive eruptions of the prehistoric volcanic eruptions on the island may be andesites; but they are not represented in Mr. Frater's collection, which, as Mr. Tyrrell's note shows, contains nothing that can be called an andesite.

TABLE OF ANALYSES.

	New Hebrides.				Japan.		
	Ambrym lava, 1913. 1	Glomeritic Basalt-Porphyrite, Mau. 2	Chocolate lava, Tanna. 3	Scoriaceous lava, Tanna. 4	Olivine-bearing hypersthene Andesite, Sakura-jima. 5	Basalt, Hizen. 6	Andose, Goto Is. 7
SiO_2	49·26	46·78	57·041	56·755	60·59	52·19	48·33
Al_2O_3	17·18	21·22	19·512	21·096	17·77	19·74	16·29
Fe_2O_3	5·47	4·63	5·499	4·521	1·23	4·72	3·24
FeO	6·10	6·17	2·714	3·021	5·59	6·28	8·73
MgO	4·28	4·30	none	trace	2·39	2·24	5·70
CaO	10·78	12·07	8·157	9·014	6·34	6·99	8·50
Na_2O	3·20	1·40	2·831	2·804	3·04	3·48	3·59
K_2O	1·76	·64	2·375	3·272	1·68	2·04	1·49
TiO_2	0·89	1·20	—	—	0·71	—	2·40
P_2O_5	0·37	·31	—	—	0·08	—	·79
H_2O at 105°	0·12	1·44	·201	·241	0·59	1·25	·82
,, at red heat	0·90				0·23		
MnO	—	trace	2·053	trace	0·24	incl. ·06	
Cr_2O_3	—	·05	—	—	—		·11
SO_3	—	—	—	—	0·23		
	100·31	100·21	100·383	100·724	100·71	98·99	99·99
Quartz	—	—			16·81	3·2	—
Felspar	64	59			64·74	73·3	63·2
Diopside	22	24 (pyroxene)			0·28	2·1	11·0
Hypersthene	—	—			14·33	12·2	2·7
Olivine	5	10			—	—	11·5
Magnetite and Ilmenite	9	7			3·14	6·7	9·2

1. Boiteau, in Lacroix, 1914, p. 493.
2. Mawson, 1905, p. 470.
3. Liversidge, 1887, p. 236.
4. Liversidge, 1887, p. 237.
5. S. Tanaka, in Koto, 1916, p. 180.
6. Ono, quoted in Iddings, 1913, p. 615.
7. Yokoyama, quoted in Iddings, 1913, p. 615.

6. General Relations of the Ambrym Eruptions.

Notwithstanding the small eruptions on Ambrym which appear to have occurred throughout the nineteenth century, its volcanoes appear to have been comparatively quiescent between about 1820 and 1880. Then, as its share in the period of more active vulcanism which was begun by the Krakatoa eruption in 1883, and the explosion of Tarawera in New Zealand in 1886, Ambrym suffered from the violent eruptions of 1894 and 1913. This period has been marked in the circum-Pacific area by the following eruptions.

The series of great circum-Pacific eruptions began with the explosion of Krakatoa in 1883, and of Tarawera, New Zealand, and

Niauafau in the Tonga Islands in 1886. In 1894 was the first great eruption of Ambrym since about 1820; in 1902 began the eruptions of Savaii, which were repeated in 1905 and 1906; in 1902 happened the explosive eruptions of Mts. Collima and Santa Maria in Central America, followed by those of Mts. Pelée and St. Vincent in the Atlantic border of the West Indian area; in 1906 occurred the eruptions of Topia and Fanua-lai; in 1908 that of Puna in Hawaii, and in 1909 that of Korintzi, Sumatra; in 1912 the explosion of Katmai in Alaska caused sunset glows in Europe; Sangir Island, on the edge of the Pacific, between the Philippines and Celebes, broke into eruption in March, 1913, followed by that of Ambrym in December of the same year.

The two eruptions with which it is natural to compare the Ambrym outbreak of 1913 are that of Tarawera, which it resembles by the formation of a volcanic trough by explosions along a fissure, and that of Sakura-jima in Kyusu, Southern Japan, in 1914. That eruption was practically contemporary with the outbreak of Ambrym, and it has been described in detail by Professor Koto (1916, 1 and 2). It began towards the end of 1914 with small earthquakes and with eruptions from Kirishima, 34 miles north of Sakura-jima, in November and December, 1913; on January 12, 1914, Sakura-jima was devastated by an explosive eruption which lasted for nine hours; it began from the high central crater of the island, followed by the opening of two vents on the flanks of the island, the three vents being situated on a line running approximately east and west. Lava streams flowed from these vents, and one stream crossed the Strait of Seto and thus converted the island of Sakura-jima into a peninsula. The composition of the Sakura-jima lava is shown by the analysis, No. 5 on the table, p. 14; it is an andesite, though it contains small quantities of corroded and partially resorbed olivine. Professor Koto states that when he first saw the eruption he considered that the three linear vents were along one fissure traversing the island, and he says that the belief in such a fissure is universal (Koto, 1916, 2, p. 138). He has, however, himself come to the conclusion that the evidence for this fissure is not convincing. He regards Sakura-jima as built up around three centres, and that the recent eruption found outlets at the weakest points, as determined by the compound structure of the island. The fact that these were linear he apparently regards as a coincidence. In an interesting transverse section through the island he explains the recent eruption as discharging a central chamber partly through a vertical central pipe, but mostly through the lateral outlets at lower levels. There appears nothing inconsistent in this arrangement with the determination of the position of the lateral and central vents by a plane of weakness along an east and west fissure. The existence of such a fissure can only be a matter of conjecture as regards Sakura-jima, but the evidence for it at Ambrym appears conclusive.

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—— *Pacific Islands*. 1908. Vol. ii, 4th ed.: xxiv, 463 pp.

II.—THE SO-CALLED COPROLITES OF ICHTHYOSAURIANS AND LABYRINTHODONTS.

By ARTHUR SMITH WOODWARD, LL.D., F.R.S.

(PLATE XXXIV.)

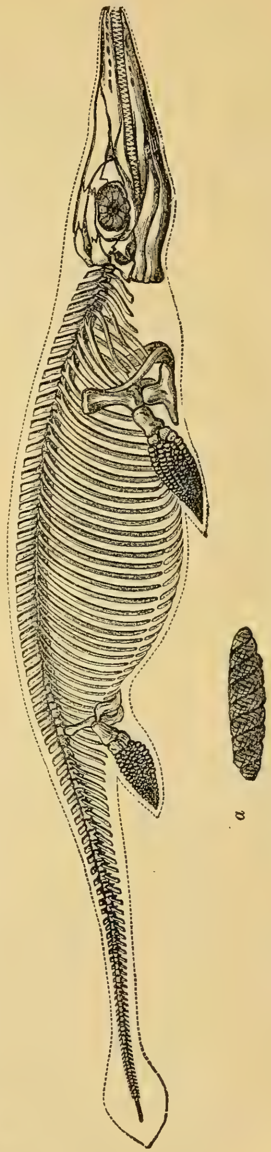
IT appears to be still generally supposed that the Ichthyosaurians differed from all modern reptiles in having a short intestine with a spiral valve, like that of the more generalized fishes; and the supposition is rendered all the more plausible by the common belief that some at least of the Labyrinthodonts were similarly characterized. In each case, it is true, coprolites or masses of partially digested food, marked with the line of an intestinal spiral valve, are often found in the same strata as the skeletons; but, so far as I have been able to discover, no instance is known in which the spirally-marked coprolite actually occurs in its natural position in the fossilized animal.

When Buckland first recognized the nature of coprolites he observed that the spiral form resembled that of the intestinal contents of a shark or skate[1]; but those of the shape in question occurred so abundantly with the skeletons of marine reptiles in the Lower Lias of Lyme Regis, that he felt no hesitation in referring them to the latter. In fact, he wrote: "The certainty of the origin I am now assigning to these Coprolites is established by their frequent

[1] W. Buckland, "On the Discovery of Coprolites, or Fossil Fæces, in the Lias at Lyme Regis and in other Formations": Trans. Geol. Soc. [2], vol. iii, pp. 223–36, pls. xxviii–xxxi, 1829.

presence in the abdominal region of the numerous small skeletons of Ichthyosauri, which, together with many large skeletons of Ichthyosauri and Plesiosauri, have been found in the cliffs at Lyme, and supplied to various collectors by the skill and industry of Miss Mary Anning. I have two of these skeletons, in each of which the Coprolites are very apparent, *but flattened.*" The last remark (here italicized) is especially noteworthy, because it is evident that Buckland himself had not observed the spirally-marked form actually within the skeleton. As proved by his figures in the *Bridgewater Treatise* (pls. xiii, xiv), he had only seen the same kind of partially digested food which often occurs in well-preserved specimens.

In the Lower Lias of Lyme Regis, indeed, the remains of large sharks (*Hybodus* and *Acrodus*) are as abundant as those of marine reptiles. I am therefore inclined to refer the problematical coprolites to these fishes, in which they would be normal, rather than to the Ichthyosaurians, in which they would be abnormal. Professor Eberhard Fraas has already arrived at the same conclusion in his well-known work on Ichthyosauria.[1] He points out that the spirally-marked coprolites do not always occur in the same deposits as the Ichthyosaurian skeletons, and that most of them, at any rate, probably belong to fishes, especially Selachians. That the short intestine with a spiral valve has always characterized the sharks is shown by its beautiful preservation in a specimen of the Devonian *Cladoselache* in the British Museum, drawn in Plate XXXIV. Here there can be no doubt about the interpretation of the appearances in the fossil, such as exists in reference to one



Restoration of a skeleton of *Ichthyosaurus* from the Lower Lias of Lyme Regis, with a spirally-marked coprolite (*a*) beneath, as published in Owen's *Palæontology*, 1860–1, p. 221.

[1] E. Fraas, *Die Ichthyosaurier der süddeutschen Trias- und Jura-Ablageungen*, p. 34 (Tübingen, 1891).

of the ganoids from the Bavarian Lithographic Stone, *Asthenocormus* [*Agassizia*] *titanius*.[1]

Assuming that Buckland's determination of the coprolites of *Ichthyosaurus* was correct, Gaudry[2] seems to have been the first to ascribe similar coprolites to a Labyrinthodont. He was then followed by von Ammon[3] and Neumayer.[4] In these cases again, however, the coprolites and skeletons were merely found in the same stratum, the one fossil never actually within the other. Though coprolitic matter is sometimes seen in the common *Archegosaurus* and other genera, it has never been observed to exhibit the spiral impression. Indeed, the only Labyrinthodont—a small Branchiosaurian—in which the whole course of the alimentary canal has been clearly distinguished, agrees in its digestive arrangements with an ordinary salamander.[5] Fritsch was therefore probably right when he concluded[6] that the coprolites bearing marks of a spiral valve, found in the same strata as the Labyrinthodonts, could scarcely belong to these animals, but must rather be referred to the associated selachian and ganoid fishes.

There is thus no reason for believing that either the earliest Amphibians or the earliest Reptiles retained the peculiar structure of the intestine which characterized the ancestral Fishes.

EXPLANATION OF PLATE XXXIV.

Ventral view of a shark (*Cladoselache clarki*) from the Upper Devonian of Berea, Ohio, U.S.A., showing the intestine (*int.*) with a spiral valve, filled with partially digested food ; one-sixth nat. size. British Museum, No. P. 9271.

III.—On the Unconformity between the Cretaceous and Older Rocks in East Kent.[7]

By Herbert Arthur Baker, B.Sc., F.G.S.

(WITH TWO MAPS AND SECTION IN TEXT.)

In a previous paper[8] the writer briefly alluded to the evidence, as known from the deep borings in East Kent, afforded by the Palæozoic and Mesozoic rocks, of the operation of a posthumous

[1] B. Vetter, Mittheil. k. mineral.-geol. Mus. Dresden, pt. iv, p. 105, 1881 ; C. R. Eastman, Mem. Carnegie Mus., vol. vi, p. 416, 1914.

[2] A. Gaudry, "L'Actinodon" : Nouv. Archiv. Mus. d'Hist. Nat. Paris, ser. II, vol. x, p. 19, text-fig. 8, 1887.

[3] L. von Ammon, *Die permischen Amphibien der Rheinpfalz*, p. 102, pl. iv, fig. 4 (Munich, 1889).

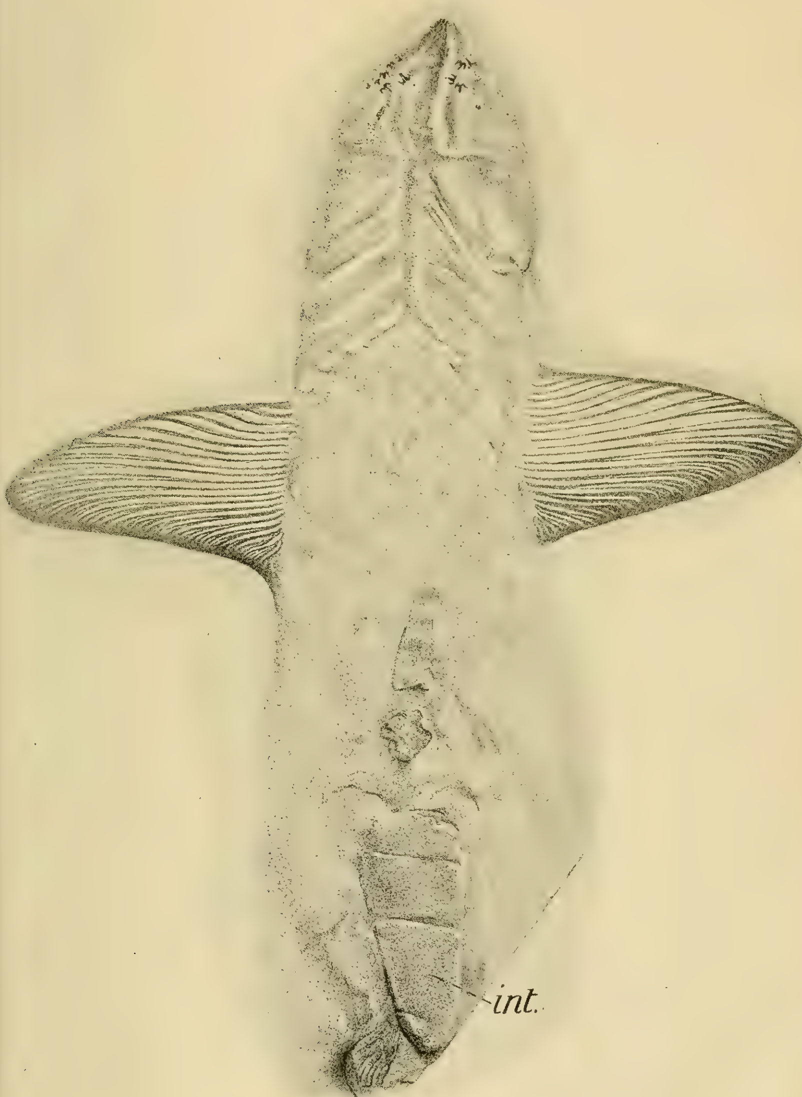
[4] L. Neumayer, "Die Koprolithen des Perms von Texas" : *Palæontographica*, vol. li, pp. 121–8, pl. xiv, 1904.

[5] R. L. Moodie, "The Alimentary Canal of a Carboniferous Salamander" : *Amer. Nat.*, vol. xliv, pp. 367–75, with figs., 1910 ; also *The Coal Measures Amphibia of North America*, pp. 26, 59, figs. 7, 14, Carnegie Institution, 1916.

[6] A. Fritsch, *Fauna der Gaskohle*, etc., vol. ii, p. 59, 1885.

[7] [This article and its illustrations were sent by the author to the Geological Magazine on September 27, 1917, and set up in type on October 9, but publication was deferred through want of space until this month. The author has sent a brief note, dated, at sea, November 14, which has been inserted at the end of his paper (see p. 549).—Ed.]

[8] Geol. Mag., Dec. VI, Vol. IV, No. 639, September, 1917, pp. 398–403.



FOSSIL SHARK, Upper Devonian.

OHIO, U.S.A.

axis of unrest, probably of Charnian affinity. This conception receives further support from a study of the special characters exhibited by the Wealden of East Kent and the nature of the unconformity between these strata and the Mesozoic and Palæozoic rocks underlying them.

When the composition of the sub-Cretaceous surface in East Kent is investigated it is seen to consist, in the north-east, in the neighbourhood of Walmestone, Mattice Hill, and Ebbsfleet, of Palæozoic rocks (Middle Coal-measures). A little to the north of Ebbsfleet, in the vicinity of Ramsgate, the sub-Cretaceous surface must be composed of the outcrop of the Carboniferous Limestone. South-westward of the outcrop of Middle Coal-measures, in the neighbourhood of a N.W.–S.E. line passing through Stodmarsh, occurs an area where the surface is composed of Bathonian. There can be no doubt that these Bathonian strata once extended further north-east and were overlapped in their turn by the Oxfordian, Corallian, and Kimmeridgian (see Section, p. 548), but these Upper Jurassics, and the Bathonian itself in part, have been removed by the severe pre-Cretaceous and early Cretaceous denudation to which the East Kent area was subjected. This sub-Cretaceous outcrop of the Bathonian is followed south-westward successively by outcrops of the Oxfordian, Corallian, and Kimmeridgian. In the south and west, westward of Ellinge, the Portlandian follows the Kimmeridgian in normal sequence, but makes no feature at the sub-Cretaceous surface owing to its being concealed by an overlap of the Purbeck. It appears likely that this overlap is an unconformable one. At Dover the coarse, freshwater Wealden gravels rest directly upon an irregularly worn surface of Kimmeridge Clay, but Mr. Lamplugh considers that there is at least a strong probability that marine sedimentation continued in this area into Portlandian times, though it is less likely that the Purbeck Series was ever developed here.[1] At Ellinge the Portlandian is missing, the Purbeck resting directly on the Kimmeridgian. It would appear, then, that the Purbeck cuts across the Portlandian on to the Kimmeridgian in this area. Further, at Brabourne the Purbeck strata comprise clays and sands with a strong green tint (perhaps due to the presence of glauconite, which is so often associated with non-sequential deposition), and contain also a remarkable breccia of peculiar composition, similar in character to that seen in the Purbecks of Hartwell, Bucks, and elsewhere, the occurrence of which appears to be associated with local unconformities.

It is unfortunate, from the point of view of the cartographer, that so many of these borings in East Kent were made by chisel, and that there is, in several instances, doubt concerning the precise sequence in the Jurassic strata passed through. It is beyond doubt, too, that this area has been largely affected by faulting, and the application of cartographical methods to the available data becomes in consequence a matter for careful consideration. It does not appear possible, in the present state of our knowledge, to do more than show the positions

[1] Lamplugh & Kitchin, *On the Mesozoic Rocks in some of the Coal Explorations in Kent* (Mem. Geol. Surv., 1911, p. 20).

of the various belts of Jurassic strata, and indicate, in a general way, the approximate positions of certain boundaries. This is done in Map below, Fig. 1.

In a general way, then, it can be seen that the deposition, subsequent upheaval and denudation, and imparted strike and dip of

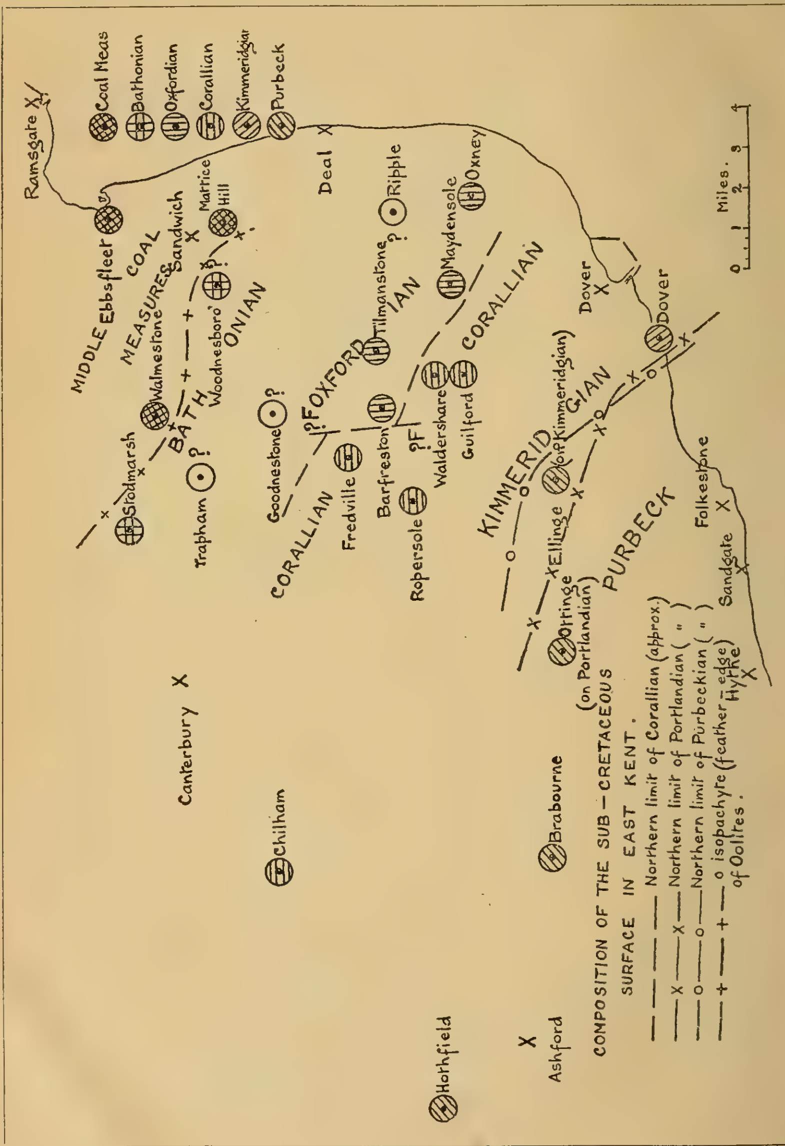


FIG. 1.

the Jurassics of East Kent are distinctly related to the movements of an axis of unrest lying to the east and north of Kent and possessing a N.W.–S.E. alignment.

Further west in Kent the Bobbing boring showed the sub-Cretaceous surface to be composed of Oxfordian strata, as did also that at Chatham Dockyard, thus demonstrating that the Oxfordian outcrop pursues the same general north-westerly or west-north-westerly direction for a considerable distance.

A point of interest concerning the position of the northward limit of the Corallian outcrop in East Kent may be noted. It will be observed that the line passes south of Oxney and Maydensole, north of Waldershare, and south of Barfreston, and then turns sharply northward in the neighbourhood of the Snowdown sinking (between Fredville and Barfreston) and resumes its general north-westerly course northward of Fredville. This deflection may perhaps be due to proximity with some anticlinal disturbance, but is more probably the indication of a pre-Cretaceous dip-fault here, possessing a westerly downthrow, which has resulted in a lateral displacement of the outcrops southward on the eastern side of the fault. In this connexion it is interesting to recall the anomalous dip of the Coal-measures observed at the Snowdown Colliery, where, instead of a dip of about 3° in a direction 35° west of south, as observed in the Tilmanstone Colliery, one of 2½° in a direction 20° north of east was found. It appears likely that faulting may have taken place here in consequence of the occurrence of a sagging movement in the south-west during deposition under isostatic conditions (see below).

The denudation of the sub-Cretaceous surface in East Kent obviously reached an advanced stage, and the area must have been reduced almost to a smooth peneplain before the deposition of the Wealden upon it. Probably, too, in earliest Cretaceous times the peneplain was corraded to some extent by stream action prior to the commencement of deposition, but not sufficiently so to produce any very marked variations in level upon it. If we eliminate the effects of post-Lower Cretaceous movements from the area by correcting the present base of the Gault here to a datum-plane at Ordnance Datum and consider the levels of the base of the Wealden in relation to it, the latter is seen to present the form of a plain possessing a very gentle southerly slope, the difference in level between the highest and lowest points upon it being less than 200 feet.

Seeing that in East Kent "the strata between the Oxford Clay and the main limestones of the Great Oolite Series . . . appear to represent a continuous sequence of marine deposits",[1] and also that "the deposition of clayey sediments went on uninterruptedly from Oxfordian to Kimmeridgian times",[1] the advanced stage to which the denudation attained is at first sight surprising, but on reflection it will be seen that denudation in the north-east must have been contemporaneous with deposition in the south-west during the latter part of Jurassic times. The general movement of uplift of the British region in Portlandian times must have exposed to denudation an area of Kimmeridge Clay fringing the Palæozoic ridge in the

[1] Lamplugh, loc. cit.

north-east while deposition of Portlandian sediments was in progress in the south-west. This state of affairs persisted into Purbeckian times, and was probably accentuated by differential movement. Direct posthumous uplift along the axis may have occurred in post-Portlandian times, but it seems likely that we have in East Kent, on the western flank of the ancient ridge, an illustration of the operation of the principle of isostasy, a sagging of the area of deposition in the south-west, under the weight of the great accumulation of Jurassic strata, being compensated by concomitant uplift in the north-east. Differential movement of this character was apparently taking place in Purbeckian times, for although the Purbeck appears never to have extended far to the north-east, yet it transgresses on to the Kimmeridgian.

Passing on now to consider the character of the Cretaceous rocks which overstep the successive members of the Jurassic until they rest upon the Palæozoic floor, the writer ventures to remark that it would probably be difficult to find a happier illustration of the utility of constructing maps of isopachyte systems of strata than that afforded by the Wealden of East Kent. The isopachytes are found to throw a very interesting light upon the question of the conditions under which these strata were deposited (see Map 2).

It is immediately apparent that the isopachytes are of a character very different from that possessed by those of a marine formation. They are clearly the lines of an estuarine deposit, and indicate plainly that the Wealden of East Kent was deposited by a river flowing from the north-east. In the view of the writer this river was consequent upon the easterly Charnian ridge. South of Woodnesborough it appears to have divided into two streams which turned south-east and flowed as subsequent or strike streams into the Wealden lake. The southerly slope of the land being now exceedingly gentle in the East Kent area, in consequence of much levelling up having been effected by the steady accumulation of great wedge-like masses of Mesozoics to the south-westward, local conditions became significant in deciding the course of the streams when the influence of the primary ridge began to die out with distance. The course of one stream appears to have been determined to some extent by the Snowdown disturbance, and it appears to have selected the Oxford Clay outcrop for some distance in preference to the harder Corallian limestones. Similarly, the more westerly stream appears to have selected the outcrop of the Kimmeridge Clay, and the erosion of the later Jurassics from the Dover area was doubtless due to its agency.

It is interesting to consider the nature of the Wealden sediments in the light of the information afforded by the map. Mr. Lamplugh, in the Survey memoir,[1] has expressed the opinion that the Wealden section in the Dover shafts offers strong indication of the inflowing of a river from the north-east. The present map shows the correctness of this view. He expresses surprise, however, at the seeming lack of Mesozoic material among the Wealden sediments, in view of the fact that such a river must have crossed an area of ancient

[1] Lamplugh, loc. cit.

quartz-veined rocks ringed round by Mesozoic formations. A little consideration will now show that such a seeming absence of Mesozoic débris need occasion no surprise. That the river must have flowed over bare Palæozoic rocks during by far the greater part of its course is quite obvious, for this area of bare Palæozoic extended (in Wealden times) as far to the south-west as Walmestone and Deal, and the river did not arrive at the neighbouring Mesozoic area until it had attained its lower reaches. Nevertheless this apparent absence of Mesozoic material from the Wealden sediments can be

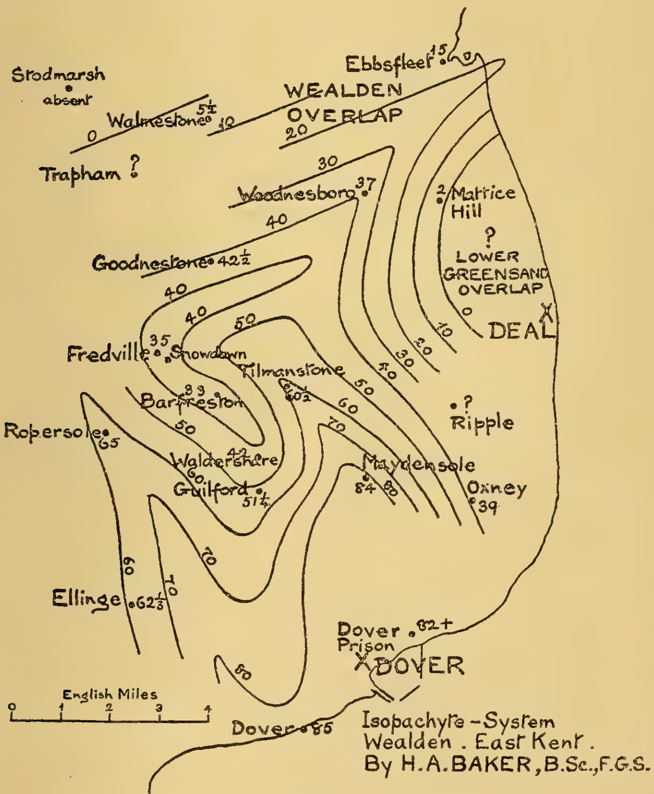


FIG. 2.

only a seeming one. Mesozoic débris must be there, but its presence is doubtless masked by the preponderance of the ancient quartzose rocks. The river must have possessed greater velocity during the earlier part of Wealden times, in view of the steady movement of submergence which was taking place, and from the character of the Hastings Beds in East Kent it can be seen that the abrading and transporting power of the stream in this area must have been considerable, only the coarser portion of its burden having been deposited

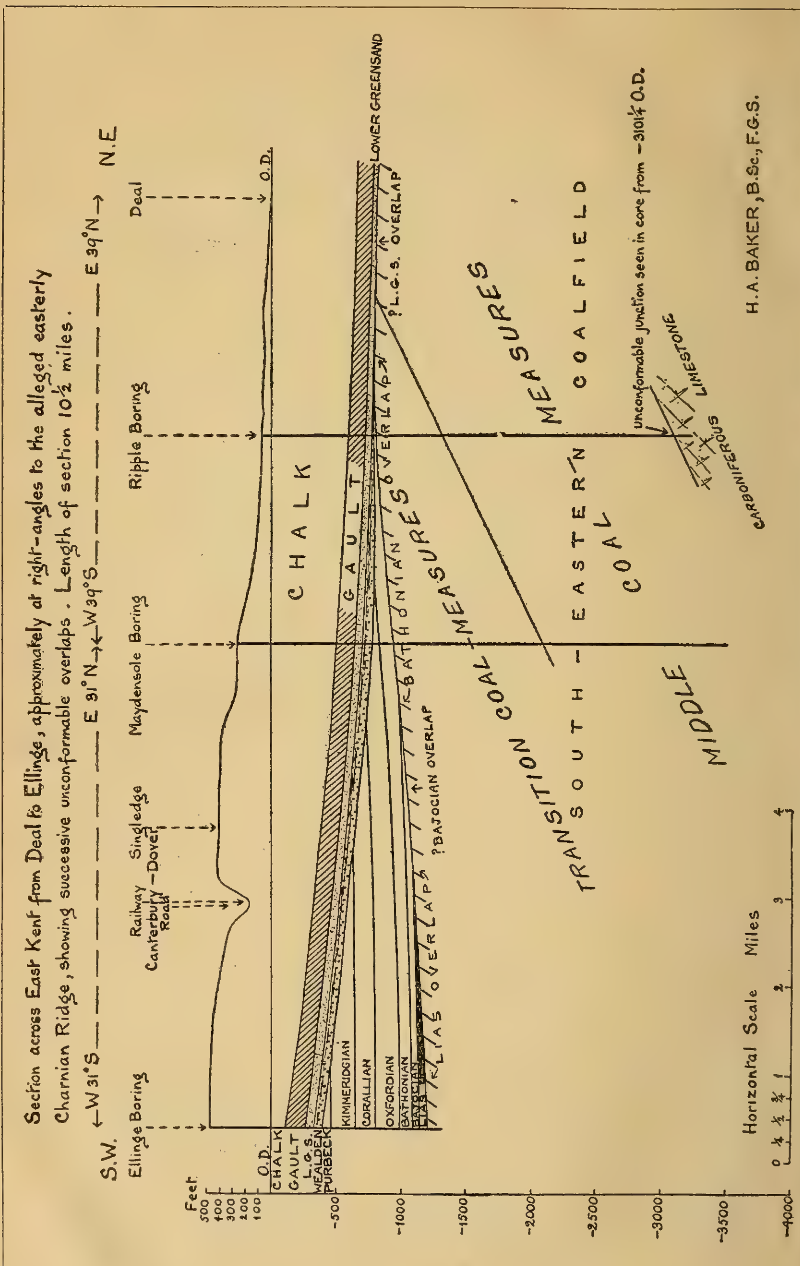

Section across East Kent from Deal to Ellinge, approximately at right-angles to the alleged easterly Charnian Ridge, showing successive unconformable overlaps. Length of section 10½ miles.
S.W.
N.E
←W 31° S
E 31° N→←W 39° S
E 39° N→
Ellinge Boring
Railway
Canterbury–Dover Road
Singledge
Maydensole Boring
Ripple Boring
Deal
O.D.
CHALK
GAULT
L.G.S.
WEALDEN
PURBECK
KIMMERIDGIAN
CORALLIAN
OXFORDIAN
BATHONIAN
BAJOCIAN
LIAS
LOWER GREENSAND
?L.G.S. OVERLAP
LIAS OVERLAP
?BAJOCIAN OVERLAP
BATHONIAN OVERLAP
TRANSITION COAL-MEASURES
MEASURES
SOUTH-EASTERN COALFIELD
COAL
MIDDLE
Unconformable junction seen in core from −3101¼ O.D.
LIMESTONE
CARBONIFEROUS
H. A. BAKER, B.Sc., F.G.S.
Feet
500
400
300
200
100
−500
−1000
−1500
−2000
−2500
−3000
−3500
−4000
Horizontal Scale Miles
0 ¼ ½ ¾ 1 2 3 4

FIG. 3.

here. The finer portion must have been dropped further on in its course. Possessed of this corrasive power in East Kent, erosion of the Mesozoic area of its bed must have been inevitable, but doubtless the finer part of the eroded material was carried beyond the area. Rarity of Mesozoic débris is therefore to be expected in the Wealden of East Kent, and where Mesozoic fragments do occur they are probably of large size and marked angularity. Comparison of the details yielded by some of the borings suggests that the Mesozoics in East Kent underwent erosion in early Wealden times, although it must be borne in mind that allowance must be made for the general pre-Cretaceous denudation of the area. For example, the sites of the Tilmanstone shaft and the Barfreston boring both lie on the sub-Cretaceous outcrop of the Oxfordian, and since Tilmanstone lies a little to the north-east of Barfreston we should expect the thickness of Oxfordian passed through to be rather less there. In actuality, only 3 feet of Oxford Clay remain at Tilmanstone, whereas 102 feet were passed through in the Barfreston bore. It would appear, then, that the early Cretaceous strike-stream which traversed the outcrop of the Oxford Clay in the neighbourhood of Tilmanstone was responsible for a considerable amount of erosion.

With continued submergence Weald Clay times approached, and delta conditions, ushering in the marine invasion of the Lower Greensand, began to prevail. The waters of the Wealden lake encroached northward upon East Kent, the velocity of the streams was checked, finer sediments began to be deposited in quantity, and base-level conditions were realized. The spreading waters united the streams into a single sheet. The evidence shows that the main stream and its two subsequent branches had become united into a single sheet of water before the commencement of Weald Clay times. Higher ground, separating the two subsequent streams from each other, appears to have existed in the neighbourhood of Fredville, yet 28½ feet of Hastings Beds occur here. To the north-east, however, the velocity of the stream still remained such that deposition had not yet commenced. Probably in this area the stream was active in removing from the Palæozoic floor some of its Bathonian covering. With the advent of Weald Clay times, however, deposition proceeded over the whole area under water, and the surface so long exposed to denudation was finally buried. In the neighbourhood of Deal a small area of Coal-measures remained uncovered until Lower Greensand times, and at and near Stodmarsh an area of Bathonian remained until Gault times.

Note.—After the proofs of this paper had been sent to the Editor additional information became available in consequence of the publication of the *Summary of Progress of the Geological Survey for 1916* (Mem. Geol. Surv. 1917). Details concerning three additional borings (J. Pringle, Appendix II), viz., at Bere Farm (1¾ miles north-east of Dover), Elham (close to Elham Station), and Folkestone, are now to hand. The Bere Farm boring shows the sub-Cretaceous surface there to be composed of Corallian Limestone, as was expected, although the thickness of the Wealden (42 feet) is less than might have been expected. The Elham and Folkestone borings show the south-westerly thickening of the Wealden (153 feet and 218 feet respectively), but each apparently demonstrates the entire absence of both Purbeck and Portland rocks.

Mr. G. W. Lamplugh (Appendix IV) discusses the underground range of the Jurassic and Lower Cretaceous rocks in East Kent, and is more fortunately situated than the present writer (who has been away at sea) in having information furnished by a further twelve borings to work upon.

November 14, 1917.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

November 8, 1917.—Sir J. J. Thomson, O.M., President, in the Chair.

The following paper was read :—

"The Structure, Evolution, and Origin of the Amphibia. Part I: The 'Orders' Rachitomi and Stereospondyli." By D. M. S. Watson, M.Sc., Lieut. R.N.V.R. (Communicated by Professor J. P. Hill, F.R.S.)

In this paper all known genera of Rachitomous and Stereospondylous Stegocephalia are reviewed, the brain-case and basi-cranial region, hitherto practically unknown, being described more or less completely, and much new information about other regions set down. It is shown that there are a series of characters which change steadily with time in all Labyrinthodontia. The more important of these changes are—

1. The gradual reduction and final loss of basi-occipital, basi-sphenoid, and supra-occipital bones and cartilages.
2. The gradual replacements of basi-pterygoid processes of the basi-sphenoid by expansions of the para-sphenoid, and finally of the ex-occipitals with which the pterygoids articulate.
3. The gradual increase in size of the inter-pterygoid vacuities, and of the para-sphenoidal rostrum.
4. The gradual regression and final disappearance from the skull of a foramen for the hypoglossal nerve.

It is pointed out that these characters, which are seen to arise within these two groups, are those which have always been regarded as the diagnostic features of the class Amphibia, and that it is certain that they have arisen independently in at least three great orders.

Finally, it is shown that a hypothetical ancestor of the Rachitomi obtained by projecting backward the evolutionary trends shown in these and other series of characters which change regularly with time, is actually realized in the Embolomerous Amphibian *Pteroplax*.

II.—Geological Society of London.

November 7, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following is an abstract of a lecture on "The Nimrud Crater in Turkish Armenia" delivered by Felix Oswald, B.A., D.Sc., F.G.S. :—

The Nimrud volcano, one of the largest volcanic craters in the world, is situated on the western shore of Lake Van, and was surveyed and investigated geologically for the first time by the speaker in 1898. The western half of the crater is occupied by a deep lake of fresh water, while the eastern half is composed of recent augite-rhyolites, partly cloaked in white volcanic ash. The crater wall is highest on the north (9,903 feet), rising in abrupt precipices over 2,000 feet above the lake (7,653 feet). The southern wall is also precipitous, but only reaches the height of 9,434 feet (the south-eastern part). A large slice of the crater wall has slipped down on the south-west, so as to form a narrow shelf, 800 feet above the lake. The crater is nearly circular, 8,405 yards from west-south-west to east-north-east, while the transverse axis is 7,905 yards. The lowest points lie on the long axis, reaching only 8,139 feet on the western and 8,148 feet on the eastern rim.

The crater wall has an external slope of 33° on the south and east, where it consists exclusively of overlapping lenticular flows of augite-rhyolite and obsidian. On the south-west, west, north-west, and north these are capped by thin sheets of cindery basalt which must have possessed great fluidity, extending for many miles to form wide plains of gentle slope and great fertility down to Lake Van on the east and into the Plain of Mush on the west. These basalt-flows dammed up the north-east to south-west valley between the Bendimahi and Bitlis Rivers, and thus brought Lake Van into being.

The history of the Nimrud volcano may be summarized as follows from the speaker's observations:—

1. Its forerunner was the Kerkur Dagh on its southern flank—a denuded mass of grey augite-trachyte, rising to 9,000 feet, and crowned by many peaks. It was probably erupted in the Pliocene Period, subsequently to the folding of the Armenian area, in which the latest folded rocks are of Miocene (Helvetian–Tortonian) age, occurring north of the Nimrud Dagh and consisting of limestones with corals (*Cladocora articulata*, *Orbicella defrancei*, etc.), *Lithothamnion*, Foraminifera (Lepidocycline *Orbitoides*, *Amphistegina*, etc.), beds of *Pecten* (*P. urmiensis*, etc.) and of oysters (*Alectryonia virleti*). Nimrud and the other numerous volcanoes of Armenia came into existence at a period when the sedimentary rocks could no longer be folded, but were fractured along definite lines, and Nimrud is situated on the great fracture transverse to the Armenian folds at the apex of their bending round from the Antitauric (west-south-west to east-north-east) to the Persian (north-west to south-east) direction, and it also marks the point of intersection of this fracture with a great north-east to north-west fracture (Caucasian direction), which delimits on the south Lake Van and the faulted depression of the Plain of Mush, abruptly cutting off the Tauric horst of pre-Devonian marbles and mica-schists.

2. Numerous flows of augite-rhyolite built up the vast cone of the Nimrud Dagh, and the increasing pressure on the central vent became relieved by extrusions of augite-trachyte along radial fissures, forming the present promontories of Kizvag, Zighag, and Karmuch.

3. A presumably long period of inactivity was followed by violent explosions destroying the summit of the cone, and from this crater (smaller than the present one) vast lava-flows of a very fluid basalt (crowded with phenocrysts of labradorite, pale-green augite, and some olivine) flooded the country and filled up the Bitlis and Akhlat valleys, which have since then been eroded a little below their former depth. The Sheikh Ora crater of basic tuff (now breached by Lake Van) probably belongs to this period.

4. Further explosions widened the crater, in which a large lake was formed, while the eastern half of the crater became filled by a succession of outflows of augite-rhyolite, in which numerous blow-holes were drilled, bringing to the surface large blocks of basaltic agglomerate and also affording sections showing the transition downwards from obsidian, spherulitic obsidian, and spherulitic rhyolite to banded augite-rhyolite (with sanidine and green augite in a micropœcilitic ground-mass).

5. The last eruption was recorded in 1441 by a contemporary Armenian chronicler, and resulted in the extrusion of a very viscous augite-rhyolite along a north-to-south zone of weakness, both inside the Nimrud crater, where it separated off part of the large lake to form the shallow, so-called "hot lake", and also to the north of Nimrud, where it rose up fissures and in a small crater.

6. A violent earthquake in 1881, which destroyed the village of Teghurt, at the eastern base of the crater wall, was the last sign of activity; but earthquakes are still frequent in the Plain of Mush, at the western foot of the Nimrud Dagh, and recent fault-scarps are clearly visible along the borders of this faulted depression.

The speaker mentioned that he had presented his model of the crater to the Museum of Practical Geology (Jermyn Street) and the rocks and slides to the British Museum (Natural History), where his fossils from Armenia are already preserved.[1]

A short discussion followed, and the thanks of the Fellows present were accorded to Dr. Oswald for his lecture.

CORRESPONDENCE.

COAL IN THE SILURIAN AT PRESTEIGN.

Sir,—Mr. Cantrill's article in the November number of this Magazine on the boring for coal in Silurian and Longmyndian rocks at Presteign (pp. 481–92) is interesting in throwing light upon one of the most flagrant examples of the ignoring of geological evidence in exploits of this nature. As there must have been some grounds for the impression in the locality that coal existed there,

[1] Lantern-slides of many unpublished photographs and drawings of the Nimrud crater and its surroundings, a model coloured geologically (scale, 1 inch = 1 mile), and a series of rock-specimens and rock-sections were exhibited by Dr. Oswald in illustration of his lecture. A Geological Survey map of the Maclean Umtata district, Cape Province, Sheet 27, scale 3·75 miles = 1 inch, 1917 (presented by the Geological Survey of the Union of South Africa), was also exhibited.

Yours very truly
Edward Hull

without which local money probably would not have been forthcoming, I may mention that on a visit to the section last August, with Professor Garwood (whose excellent conjoint paper with Miss Goodyear, read at the Geological Society on June 6, and published in abstract in the Proceedings on June 13, 1917, has been overlooked by Mr. Cantrill in his account of work on the district), we learnt from an old quarryman, whose memory reached back many years, that it had been the custom in slack times to cart coal from the Clee Hills for lime-burning. In order to preserve the coal it was necessary to *bury* it, often in considerable quantities. Relics of these hoards are occasionally met with, and, as their history has been generally forgotten, it is very likely that these chance finds gave rise to the idea that coal-bearing beds exist in the locality.

W. W. WATTS.

HILLSIDE, LANGLEY PARK,
SUTTON, SURREY.
November 12, 1917.

OBITUARY.

PROFESSOR EDWARD HULL, F.R.S.

(WITH A PORTRAIT, PLATE XXXV.)

BORN MAY 21, 1829. DIED OCTOBER 18, 1917.

BY the death of Edward Hull, in the 89th year of his age, another of the links has been broken which connect the geologists of to-day with those of the earlier half of last century. He was born in Antrim, and came of a stock that had been settled in Ireland for at least four generations. Educated at Trinity College, Dublin, he took his degree in Arts there. It was there, also, that he was inspired with a strong bent towards geology by the prelections of Professor Thomas Oldham. That eminent man gave him a letter of recommendation to Sir Henry De la Beche, Director-General of the Geological Survey, who without loss of time found a place for him in 1850 on his staff. From the time when Hull began field-work by running sections in North Wales under J. B. Jukes, he continued for seventeen years to be employed in England, first mapping tracts in Gloucestershire and the upper parts of the Thames Valley, and then in the coal-fields of Cheshire and Lancashire. During the winter months, when the members of the staff, quitting the field, repaired to London for indoor work in the office, Hull gained the good-will of his colleagues by his imperturbable good-nature, which, in sport, they would sometimes tax to its utmost limit. But he seemed never to bear any of them a grudge, taking it all as part of the routine of Survey life. They came to recognize that beneath his foibles of manner there lay a kindly heart, ever ready to respond to kindness.

In 1867, on the separation of the Geological Survey of Scotland as a special branch, Hull's good service was rewarded by his being appointed District Surveyor and second in command on the Scottish branch. Stationed at Glasgow, he was entrusted with the mapping of the Clyde coal-field. But he had not been more than two years in this new sphere when he received further promotion by being appointed to succeed Jukes as Director of the Geological Survey of Ireland—a post which he continued to fill until he retired from official life, after a service of forty years.

The Irish Directorship was by no means a bed of roses. The staff included at least one fiery member, who, with characteristic Irish contempt for the ruling power, began opposition before the newly appointed official had set foot in Ireland, demanding that the appointment should be cancelled. When this demand was rejected, he commenced the same system of petty insubordination and opposition which had reduced poor Jukes to despair. Hull, however, as an Irishman, was probably not wholly unaccustomed to such tactics. He never succeeded in permanently silencing the malcontent, and made many an appeal to his chief in Jermyn Street for support. Indeed, no small part of his official correspondence with headquarters consisted in reports of fresh and unexpected devices of opposition. But his equanimity seemed never to be seriously ruffled. No higher testimony to his essential good-nature could be desired than the fact that he bore the perpetual worry for two and twenty years without losing either his wits or his temper. During his reign in Ireland he had the opportunity of seeing the geology of every part of the island. This wide experience gave him material for the preparation of a convenient new general geological map of the country on the scale of 8 miles to an inch. While discharging his duties in the Survey he also held the Professorship of Geology in the Royal College of Science in Dublin.

In 1891 Hull retired from official life. He was then little more than 60 years of age, and still in full possession of health and vigour. He determined to come to London and settle there in the expectation that he might find congenial employment as a practical geologist or geological engineer, especially in connexion with such matters as coal-mining and water-supply, in which he had often been consulted during his life on the Survey. He never allowed his pen to rust. The list of his memoirs, papers, and separate books is a monument of his industry. He was a voluminous writer on English geology from the beginning of his life in the Survey onwards. Some of his early papers are marked by a suggestiveness in the discussion of more or less theoretical questions which gave promise of distinction that was hardly fulfilled in his later work. His best known volume, *The Coal-fields of Great Britain*, is a useful compendium of the subject of which it treats, and has passed through five editions. Reference should also be made to his contributions to our knowledge of the geology of Palestine. He was sent to that country in 1883 by the Palestine Exploration Society, as leader of an expedition which included the future Lord Kitchener as one of its staff, the object of research being to report on the region of Mount Seir, Sinai, and Western Palestine. In later years he devoted much time to tracing on Admiralty and other charts the submarine continuations of the river-valleys of Western Europe and Western Africa.

In 1910 the retired Professor published a thin autobiographical volume, entitled *Reminiscences of a Strenuous Life.* His career, like that of many other public servants, was quiet, uneventful, and not unsuccessful. It included sufficient leisure for such work as he chose to undertake, outside the sphere of his official duties, and of this leisure he diligently availed himself in the preparation of his contributions to the scientific literature of the time. Though much of his writing may not be enduring, it must be admitted that he has left his mark on the records of English geology.

Those who knew Edward Hull best will always remember him as a leal-hearted friend, who through a long life maintained the honour of a gentleman and carried with him cheerfulness and good will wherever he went.

A. G.

Note.—On June 1, 1914, Professor Hull was one of those friends who wrote and congratulated the Editor on the completion of fifty years of the Geological Magazine, and was indeed one of the four famous geologists, then surviving, who had contributed to the 1864 volume of that journal, viz., the Rev. O. Fisher, M.A., F.G.S.; Sir Archibald Geikie, O.M., K.C.B., P.Pres.R.S., etc.; Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S.; and Professor Hull, M.A., LL.D., F.R.S., etc., Professor Hull himself having during the fifty years made 119 communications to this Magazine. We had prepared a complete list of the titles of Hull's books and papers, amounting in all to over 250. As a selected series had already been published by Professor Hull at the end of his *Reminiscences of a Strenuous Life* in 1910, and the full list would have occupied more than ten pages, we could not devote so large a space in this number, and the intention had therefore reluctantly to be abandoned.—Editor Geol. Mag.

GEORGE CHARLES CRICK.

Born October 9, 1856. Died October 18, 1917.

Born at Bedford on October 9, 1856, the son of Dr. F. W. Crick of that town, George Charles Crick was educated at the Modern School there. Subsequently he passed through a course of studies at the Royal School of Mines, South Kensington, from 1875 to 1881. His career there was noteworthy, for he successively passed 1st Class in Physics (1875–6), 1st Class in Biology (1876–7), 2nd Class in Chemistry (1877–8), 1st Class in Geology (1878–9), 1st Class in Mechanics, 2nd Class in Mineralogy, 2nd Class in Palæontology (1879–80), and 1st Class in Mechanical Drawing (1880–1), thus winning the Associateship.

For some short time he acted as one of the curators to a notorious private collector, but on January 1, 1881, he entered on duty as Clerk and Assistant Secretary to "H.M. Commission to enquire into Accidents in Mines, etc.", of which Sir Warington W. Smyth was

Chairman, and he continued to act in that capacity till the termination of the Commission in 1886.

Meantime in November, 1881, he undertook work in a voluntary capacity in the Geological Department of the British Museum (Natural History), and was then employed as a temporary Assistant in 1882; on April 19, 1886, he was taken on the establishment as an Assistant of the Second Class.

At the Museum he was given charge of the Fossil Cephalopoda, then much in need of attention, and throwing his whole heart into the work has left it one of the best arranged and indexed collections in the institution.

This group was at that time in process of being catalogued by Mr. A. H. Foord, who writes as follows: "I had the happiness of knowing the late Mr. G. C. Crick for many years, as I was intimately associated with him in the Geological Department of the British Museum. Our work running on similar lines we wrote several papers jointly for this Magazine and for the *Annals and Magazine of Natural History*. Great patience and minute attention to details were conspicuous in all his work, and his researches were therefore highly valued by students of palæontology in the branch which he made his own, viz. the Belemnites and the Ammonites. He will be greatly missed by all his colleagues." Crick further assisted Foord largely with the first two volumes of the *Catalogue of Fossil Cephalopoda in the British Museum*, issued in 1888 and 1891, and was joint author with Foord of the third volume (Bactrites and Ammonoidea, *pars*), published in 1897: whilst he compiled the *List of Types and Figured Specimens of Fossil Cephalopoda in the British Museum* (*Natural History*), which saw the light in 1898.

Sixty-seven papers, including seven written in association with A. H. Foord, and one with R. Bullen Newton, stand to Crick's credit in various scientific publications. In the course of these, seventy-four new species are described and three new genera founded (*Amphoreopsis*, *Styracoteuthis*, and *Belemnocamax*). This is quite a moderate number for any student of fossil Cephalopoda, but his inclinations were ever toward the morphological side of his subject, and especially any feature of mechanical interest. This is very evident in his beautifully constructed model of the *Ascoceras* shell, and of the guard and phragmocone of the Belemnite, as well as in the question of the attachment of the animal to its shell in Nautiloids and Ammonoids. The first instalment of his memoir on this last question, that dealing with the Ammonoidea, was brought before the Linnean Society of London in 1898, and appeared in their Transactions. This important communication was very highly esteemed, and led, in conjunction with his other work, to the award by the Geological Society in 1900 of a moiety of the Barlow-Jameson Fund. The second part of the memoir, that treating of the Nautiloidea, was practically complete at the time of his death, and it is hoped that, with other of his literary remains, this may yet be published. Indeed, it would have appeared before had it not been for the meticulous care he bestowed on all his writings, which led him to withhold them from publication until satisfied that the last possible item of information had been obtained, whilst a contributing cause of delay was to be found in the state of his health.

Never robust, he became on more than one occasion so seriously ill that his life was despaired of; still, he made marvellous recovery, and for some years had been so much better that he even participated for a time in Red Cross work. Whilst conscious himself of his precarious condition, he happily had no premonition of his sudden end, and the afternoon before was discussing with Dr. Kitson the geological age of some Ammonites from Nigeria, and making plans for future work. The following morning he passed quietly away at his Wimbledon home, and a few days later was interred at Luton.

Modest, quiet, and unassuming, ever ready to assist others, Crick endeared himself to all with whom he came in contact; even one who had not seen much of him writes "he always seemed a lovable little man". As such he will be sincerely mourned, not only by his widow, but by a very wide circle of friends.

Crick was elected a Fellow of the Geological Society in 1881; he joined the Geologists' Association in 1887; was one of the original members of the Malacological Society of London on its foundation in 1893; was elected a Fellow of the Zoological Society in 1896; and of the Royal Geographical Society in 1916. He was also a member of the Bedfordshire Natural History Society, of which his father was one of the founders, and frequently read papers before them.

B. B. Woodward.

List of the Scientific Writings of G. C. Crick.

1889. (In association with A. H. Foord.) "On the Muscular Impressions of *Cœlonautilus cariniformis*, J. de C. Sowerby, sp., compared with those of the Recent *Nautilus*": Geol. Mag., Dec. III, Vol. VI, pp. 494–8, 2 woodcuts.

1890. (In association with A. H. Foord.) "On the Muscular Impressions of some Species of Carboniferous and Jurassic Nautiloids compared with those of the Recent *Nautilus*": Ann. Mag. Nat. Hist., ser. VI, vol. v, pp. 220–4, 6 text-figs.

(In association with A. H. Foord.) "Descriptions of new and imperfectly defined species of Jurassic Nautili contained in the British Museum (Natural History)": ibid., pp. 265–91, 18 text-figs.

(In association with A. H. Foord.) "On some new and imperfectly defined species of Jurassic, Cretaceous, and Tertiary Nautili contained in the British Museum (Natural History)": ibid., pp. 388–409, 9 text-figs.

1893. (In association with A. H. Foord.) "On a New Species of *Discites* (*Discites Hibernicus*) from the Lower Carboniferous Limestone of Ireland": Geol. Mag., Dec. III, Vol. X, pp. 251–4, woodcut.

1894. (In association with A. H. Foord.) "On the Identity of *Ellipsolites compressus*, J. Sowerby, with *Ammonites Henslowi*, J. Sowerby": ibid., Dec. IV, Vol. I, pp. 11–17, pl.

(In association with A. H. Foord.) "On the *Temnocheilus coronatus*, M'Coy, from the Carboniferous Limestone of Stebden Hill, near Cracoe, Yorkshire": ibid., pp. 295–8, woodcut.

"On a Collection of Jurassic Cephalopoda from Western Australia—obtained by Harry Page Woodward, F.G.S., Government Geologist—with Descriptions of the Species": ibid., pp. 385–93 and 433–41, Pls. XII and XIII.

(Review.) "*Nanno*, a new Cephalopodan type," by J. M. Clarke: ibid., pp. 561–2.

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"On the Aperture of a Baculite from the Lower Chalk of Chardstock, Somerset": Proc. Malac. Soc., vol. ii, pp. 77–80, text-figs.

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"Note on *Vestinautilus crassimarginatus*, A. H. Foord": ibid., pp. 552–5.

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1915. "Note on *Nautilus Mokattamensis*, A. H. Foord, from the Eocene of Egypt": Proc. Malac. Soc., vol. xi, pp. 286–90, pl. and text-figs.

"On a Dibranchiate Cephalopod (*Plesioteuthis*) from the Lithographic Stone (Lower Kimmeridgian of Eichstädt, Bavaria)": ibid., pp. 313–18, pl.

1916. "Note on a gigantic Cephalopod Mandible": Geol. Mag., Dec. VI, Vol. III, pp. 260–4.
"Note on the Carboniferous Goniatite *Glyphioceras vesiculiferum*, de Koninck, sp.": Proc. Malac. Soc., vol. xii, pp. 47–52.
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1917. "Note on the type-specimen of *Crioceratites bowerbankii*, J. de C. Sowerby": ibid., pp. 138–9, pl. vii.
"Recent Researches on the Belemnite Animal": Abstr. Proc. Geol. Soc., Sess. 1916–17, pp. 12–13.

MISCELLANEOUS.

The Royal Society Medals: Awards for Scientific Research.—Of the two Royal Medals to be awarded this year by the President and Council of the Royal Society, the King has approved of one being awarded to Dr. John Aitken, F.R.S., for researches in cloudy condensations, and the other to Dr. Arthur Smith Woodward, F.R.S., F.L.S., V.P.G.S., Keeper of the Department of Geology in the British Museum (Natural History), and one of the Editors of the Geological Magazine, for his researches in Vertebrate Palæontology. We offer him our hearty congratulations on this well-merited honour. For his life and portrait see Geol. Mag. 1915, pp. 1–5, Pl. I.

The Woodwardian Professor of Geology in the University of Cambridge.—This Chair, founded by Dr. John Woodward in 1722, and rendered illustrious by Professor Adam Sedgwick, who held it from 1818 till 1872, when he was succeeded so happily by one of his former pupils, Professor T. McKenny Hughes (1873–1917), is now followed by another well-known Cambridge geologist, John Edward Marr, Sc.D., F.R.S., who for thirty years or more has fulfilled the important post of University Lecturer in Geology and College Lecturer in St. John's. This election by the Senate has been received with great satisfaction not only by University men but by geologists at large, amongst whom Professor Marr is well known and universally esteemed. A sketch of his life and work, with a portrait, as an "Eminent Living Geologist", appeared in this journal in July, 1916 (pp. 289–95, Pl. XI).

Lenham Beds and Miocene Rock from the North Sea.—Mr. R. B. Newton, who recently described these interesting deposits in the *Journal of Conchology*, xv, 1916–17 (Geol. Mag., June, July, 1917), and Quart. Journ. Geol. Soc., lxxii, 1916, respectively, has now arranged a temporary exhibition series of the two faunas. Those interested can see these specimens in the Gallery of Fossil Mollusca at the British Museum (Natural History), on request, during the next few months.

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THE EDITOR,

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